WORLD ANIMAL REVIEW

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A QUARTERLY JOURNAL DEVOTED TO WORLD DEVELOPMENTS IN ANIMAL PRODUCTION, ANIMAL HEALTH AND ANIMAL PRODUCTS

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COVER: Greece. Vlack variety of the Greek Zackel breed of sheep returning to the lowlands from summer mountain pastures in autumn.

PHOTO: FAO.

ceres medal presented to

A Ceres medal was presented to Dr Helen Newton Turner on 12 July 1978 for her outstanding work in the field of animal genetic resources and, in particular, sheep breeding and genetics. This is the first time a Ceres medal has been awarded in honour of a contribution in the field of animal science. To commemorate this event, the World Animal Review is publishing excerpts from the presentation and acceptance speeches, and from a seminar given by Dr Turner on the same day.

Dr Helen Newton Turner receiving the Ceres medal from Dr Ralph Phillips

Presentation of the Ceres medal to Dr Helen Newton Turner, by Dr Ralph W. Phillips, Deputy Director-General, FAO

When I first met Dr Turner at the National Agricultural Research Centre at Beltsville, Maryland, in 1939, I am sure that neither of us could have imagined that our paths would cross in circumstances such as these, almost 40 years later in the Eternal City. They have crossed here twice before: in 1963, on the occasion of the First World Conference on Animal Production, and in 1966, when Dr Turner was a member of an FAO Expert Panel on the Conservation of Animal Genetic Resources, which I had the honour to chair. And they crossed at College Park, Maryland, during the Second World Conference on Animal Production, in 1968. But, as recently as November 1975, when I was privileged to suggest that Dr Turner was one who should be considered for receipt of a Ceres medal, I had no thought that I might be in my present position, where one of the perquisites is now the pleasure of making this presentation.

Dr Turner has had a distinguished career in animal genetics, after having been trained as an architect, and receiving a Bachelor of Architecture from Sydney University in 1930. As some of you will remember, the world — including Australia — was in the grip of an economic depression in 1930, and jobs for architects were scarce indeed. So, two days after receiving her degree, the bright young graduate began a crash course in secretarial work. After a secretarial assignment for an architectural firm and a clerical one for the Board of Optometrical Registration, she was selected to serve as secretary to Dr (later Sir) Ian Clunies Ross, at the McMaster Animal Health Laboratory, a post she took up in August 1931. That marked the end of a potential career as an architect, and the beginning of her entry into the animal genetics field.

Among her many and varied tasks as secretary to Dr Clunies Ross was the typing of scientific papers for publication. These included papers by a statistician, Dr W.A. Carr Fraser, and she became intrigued with their content, since mathematics had been her strongest subject in

animal geneticist

the university. "Biometry", as it was then called, was a young science. But she pursued it through night courses in mathematics and statistics, and by ploughing through R.A. Fisher's "Statistical methods for research workers" on her own. Then, in August 1938, she sailed to Europe, for a year's study leave; study, which included working with Fisher and his colleagues at University College in London, and later at Rothamsted under the guidance of Dr Frank Yates.

Dr Turner left England in September 1939, just as World War II was breaking, and made her way back to Australia by way of Canada, the United States and New Zealand. It was then that our paths first crossed at Beltsville.

Upon her return to the McMaster Laboratory, Dr Turner was relieved of all clerical work, so she could concentrate entirely on statistical consulting and data analysis. Thus, she served as consulting statistician to the Division of Animal Health and Production, in Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) from 1939 until 1956, except for a period in war-related work (1942-43, and part-time from then until the war ended). During this period she did stints as a statistician in the Research and Development Section of the Department of Home Security, and in the Manpower Directorate, where she organized a register of Australian scientific personnel.

In 1954 she again went overseas for a year, to observe sheep-raising methods, and to visit animal breeding laboratories, in India and in many European countries. During that period she paid her first visit to FAO.

From 1956 to 1973, she served as Leader of the CSIRO Sheep Breeding Research Group. Since her retirement in 1973 she has been an honorary research fellow of CSIRO. I shall not attempt to even mention by title Dr Turner's many scientific contributions, but will only recall that, on the basis of her published work, she was awarded a D.Sc. by Sydney University in 1970. She has written parts of several books and over 100 scientific papers.

In addition to her deep involvement in sheep-breeding research in Australia during nearly four decades, Dr Turner contributed to the development of the sheep industry in her own country by supervising the studies and research of post-graduate students in Australian universities, by the training of extension officers in sheep and wool, and through rural broadcasting.

Dr Turner has also made many contributions in the international arena. Among her post-graduate students in Australia, there were fellows from many countries studying under FAO or Colombo Plan or other fellowships. She has also lectured and been much in demand as a consultant in various parts of the world, and presented papers at a number of international congresses and meetings.

Since Dr Turner has made her way successfully in a field that has largely been dominated by men, it should also be noted that she has taken time to give a helping hand to women along the way.

Now, Dr Turner joins other distinguished women from around the world as a recipient of the Ceres medal. These medals, first issued in 1971, underline the crucial role of women in social and economic development; women who share FAO's ideal of a world free from hunger.

Dr Turner, in recognition of your life-time of service to world agriculture, I am pleased, on behalf of the Director-General of FAO, to present to you this gold version of the Ceres medal, as a small token of appreciation for a life-time of work of which you may well be proud.

Dr Turner's speech in reply

I need hardly say how surprised I was when I was asked to donate my profile — or was it portrait — for the Ceres medal. Of the many items in my career which Dr Phillips has mentioned, I regard the Ceres medal as the greatest honour of all.

Ceres was, of course, the Roman goddess of agriculture, and in the Greek world she was identified with Demeter, who had a daughter Persephone. The Greek myths had it that Persephone was very beautiful, and she seems to have shared supervision of agriculture and fruitfulness with her mother. Her beauty, however, attracted the attention of the god of the underworld, who carried her off to Hades to be his bride.

Ceres mourned for a long time and sought her daughter everywhere. Finally the god of the underworld agreed to let her return, on condition that she ate nothing between the time of the agreement and her actual return. Unfortunately Persephone succumbed to hunger and ate just four pomegranate seeds. As a result, she was allowed to spend eight months of the year on earth, but had to go back to Hades for four months — one for each seed. Her return to earth each year was, of course, the coming of spring.

Persephone was in this way shared between the upper and lower worlds. Let us forget now about the upper and lower worlds, and think instead of the three worlds which Chairman Mao postulated — the First, Second, and Third or Developing World. FAO's work is aimed at sharing of agricultural riches among these three worlds.

There has been a change over the years in the attitude toward the technique of this sharing. A word which was formerly common has now become a rude three-letter word — aid. We no longer think of aid, but of cooperation. Sharing, not straight-out giving, is now the aim.

The United Nations Conference on Science and Technology for Development next year is, I am sure, occupying a great deal of time for people here in FAO. I hope that Conference will lead to something concrete, and I am certain its theme will be cooperation. As a result we will, I hope, be further on the road to sharing the world's riches, as Persephone was shared between two worlds.

Sheep and the smallholder

H.N. Turner

The "smallholder" is defined as one who owns less than 30 sheep, and has limited income. Many are found in parts of Europe, but in general this presentation is intended to refer to smallholders in developing countries, including India, the Near East, Africa, Malaysia, Indonesia, and parts of South America. The areas in which the sheep run may be mountainous (e.g., northern India, parts of South America), but in many cases are tropical or subtropical. They may be arid, semi-arid or wet, but in all cases are harsh. There are no fenced grazing areas. Sheep are yarded, sometimes even housed, at night, and shepherded by day onto stubble, road and canal verges, under trees, or in a few cases, rangeland grazing areas. Often flocks belonging to a number of smallholders will be put together to form a grazing band under one shepherd. In other cases, flocks from a number of owners will be banded together to migrate through quite large areas (e.g., in Iran and India).

Each region has its own breed. Some are woolless, others produce a coarse fleece of wool mixed with fibres. Much is pigmented. Very few produce what would be known on the world market as "apparel wool", that is, wool with an average diameter of under 28 μ, with little or no medullation.

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Sheep provide fibre, meat, milk, skins, dung for fertilizers or fuel. Some products reach world markets (e.g., carpet wool), but much is used locally, consumed by the growers or processed in cottage industries into items for sale, such as carpets.

Production levels for fleece and body weights are usually low: adult body weights may be as low as 25 kg, while fleece weights range from less than 1.0 to 3.5 kg. This has led in the past to a tendency to seek improvement by introducing exotic breeds. The sight of body weights for Australian Merino ewes of up to 55 kg, combined with fleece weights of 6 kg, or British breeds with even higher body weights, has led to dreams of the advantages of crossing these with local breeds. But rosy dreams have all too often turned to nightmares; exotic sheep producing 6 kg of wool under the conditions in their own homelands may not even be able to survive in the harsh environment of the indigenous animals.

This presentation will discuss six main points in relation to small indigenous flocks:

1. The need for documentation of performance of indigenous breeds, in particular their reproduction rate. (Because lambs are seen in spring and autumn, this does not necessarily mean that ewes will lamb twice a year.)
2. The need for careful comparison of the performance of indigenous breeds and their crosses with introduced breeds before any widespread crossing is undertaken.
3. Inclusion in (1) and (2) of a consideration of the market for products, and the possible effect of crossing on suitability for that market, or any changed market.
4. The rate of spread of exotic genes in a whole population.
5. Techniques for improvement by selection when flocks are small.
6. Comparison of gains from crossbreeding and selection.

Documentation

The following examples will serve to illustrate the value of information.

Until recently little had been heard of the D'man breed of Morocco. Careful documentation has revealed that this is one of the handful of remarkable breeds in the world that will reach puberty at about six months of age and lamb twice a year, with a high incidence of multiple births and high average litter size.

In Java, there are two sheep breeds, the Priangan and the Java Fat-tail. Exact figures of their reproductive performance are scanty, though steps are being taken to secure better data. It would appear, however, that they are capable of lambing more than once a year, with a high incidence of multiple births and high average litter size. Both are woolled breeds, but the wool is usually cut off and thrown

away. Sheep are grown for meat, and, in the case of the Priangan, for ram-fighting as well. A high reproduction rate is a valuable genetic asset, and it should not be assumed (as some workers in nearby tropical countries seem inclined to do) that this high performance is simply due to low latitude. Introduced breeds (from Australia, for example) will not automatically become more fecund just because they move nearer the equator. Fecundity is heritable; Merino lines exist in Australia that differ markedly in fecundity when run together in one flock. One line in particular, selected for high fecundity, has had a lambing percentage of 210, with litter sizes up to 6.

Data are needed on all aspects of performance of indigenous breeds in their harsh environments, and proper comparisons must be made with crosses with introduced breeds. These comparisons should be made not only on experiment stations, but also under the conditions where the sheep will be raised. All aspects of production need to be considered. A cross between the Javanese Fat-tail and the Australian Dormer, for example, may have a body weight 5 kg greater than the Fat-tail, but if its lambing percentage were dropped from (say) 180 to 140, what would be the final gain? Ninety wethers at 30 kg would give 2 700 kg and 70 at 35 kg, 2 450. The gain in body weight would not be enough to counterbalance the loss in reproduction rate. (These are fictitious figures; real data are needed to establish the balance.)

Currently, the author is trying to track down some historical documentation, which is even more difficult to find than recent documentation. Most people who have written about the development of the sheep industry in Australia have concentrated on the Merino, but the author has become interested in the meat sheep that preceded the Merino. These were shipped at the Cape of Good Hope and in Calcutta. The Indian sheep were greeted with scorn when they first arrived because they were so small; the scorn turned to appreciation, so it is alleged, when it was found they would lamb twice a year with a high incidence of multiple births. But what were they? The author is trying to find out. And how reliable are the statements about reproduction rate?

Garut fighting ram, near Bandung, Java, Indonesia. (Credit: H.N. Turner)

Javanese Fat-tail ewes and lambs, Madura, Indonesia. (Credit: H.N. Turner)

Evaluation of crossbreds

The amount of indiscriminate crossing with exotic breeds that occurs in many tropical countries is amazing. This is done without any attempt to compare the crossbreds with indigenous breeds, even though in some cases it has been extremely difficult to keep the exotic sheep alive and reproducing. The assumption is made, as mentioned earlier, that a breed with high production in its homeland will *automatically* improve the production of indigenous breeds in other areas.

It cannot be stressed too often that this is a fallacy. The cross *must* be assessed before widespread indiscriminate crossing is undertaken. A valuable genetic asset such as fecundity can be all too easily lost in aiming for higher fleece and body weights from exotic genes and the hoped-for gains may not even eventuate.

Two points should be remembered in relation to assessment:

— Crossbreds and indigenous sheep must be run together *in the same environment*. Conclusions drawn

Ewes of the D'man breed in Morocco. (Credit: I.L. Mason)

from data on crosses on experiment stations compared with figures from sheep out in the villages are meaningless.

— The comparison should be made under the conditions where the crosses will eventually be run, and not only under experiment station conditions.

Comparisons of performance are only the first step — it has all too often been omitted, as have the later steps, which include marketing and use of products from the crosses, and prediction of the facilities and time required to spread introduced genes through a population.

Marketing and use of products

India and the Indian Government's plans for improvement of the sheep industry may be taken as an example of the marketing and use of products.

Indian sheep-growing areas can be divided into four regions: Himalayan, Northwest Plains, Eastern and Southern Peninsular Plateau. Many flocks in all areas fall in the smallholder category.

The Government of India has had a series of five-year plans, all of which included programmes for sheep improvement. An *Ad Hoc* Committee on Sheep-Breeding appointed in 1970 made specific recommendations for every sheep-growing State, which were strengthened and supplemented by a subgroup on sheep and goat development (1973). The fifth five-year plan (1974-79) included also implementation of three assistance programmes, initiated during the fourth plan, which aim at replacing piecemeal and *ad hoc* schemes by an integrated approach ranging from land development to product utilization and including subsidies.

The detailed recommendations of the *Ad Hoc* Committee included the following:

- New breeding farms were to be established, or existing farms expanded, to produce superior rams for distribution to growers. These farms would be run by the States, in some cases with financial assistance from the Government of India.
- "Superior" rams were to be produced *either* by selection within indigenous breeds, *or* by crossing with exotic breeds.
- Certain indigenous breeds were nominated for retention as pure-breeds, either because they produced high-quality carpet wool, or because they were adapted to particularly harsh environments. (Nellore and Mandya, woolless sheep for hot, wet areas; Sonadi and Malpura, for growing coarse carpet wool in very hot dry areas; Chokla, Magra, Nali and Jaisalmeri, for producing good-quality carpet wool.)
- The level of exotic genes in farm flocks was not to exceed 50 percent, except in specifically nominated better environments, where it might rise to 75 percent.
- Some state farms were to carry out evaluation of crosses between exotic and indigenous breeds.

The object of introducing exotic breeds was twofold: to produce more fine wool for Indian commercial mills, since all India's own breeds grew coarse and medullated fleeces; and to increase body weight for extra meat production.

States were to make their own imports of exotic breeds, those chosen for wool production being the American Rambouillet and Merinos from the USSR. The Government of India also entered into a project with the Australian Government to establish a large central farm for producing pure Corriedale rams. (The Indians wanted Merinos, but were prevented from having them by Australia's export embargo.) This central farm was established at Hissar, about 160 km NNW of Delhi. Associated with it were to be State farms, partly financed by the project, on which crossbred (Corriedale × indigenous) rams would be produced for distribution to farmers.

Tremendous difficulties were encountered in the early years in keeping the Corriedales alive and reproducing; rams were even housed in an air-conditioned shed. Because of these problems, there has been a delay in implementing the associated projects; no comparison of crossbreds with indigenous sheep has yet been

A D'man ewe with triplets. (Credit: I.L. Mason)

made, nor any evaluation of the crossbred wool and its likely use. These steps are an essential part of any such project, and are to be undertaken now that conditions at the Hissar farm itself have improved and the flock is a viable one.

At the State farms designed to produce crossbred rams, the pure Corriedale rams had to be isolated from the indigenous ewes because of disease risks, artificial insemination being used for mating. Once frozen semen for rams becomes a practical proposition, some of these problems can be avoided; a smaller stud can be maintained in a kinder environment, and frozen semen distributed from there. The need for comparison of crosses with indigenous sheep will, however, remain, together with the need for product evaluation.

The Government of India is aware of the need to study market requirements in relation to crossbred wool, and two points can be made.

Hand processing of finer wools. Difficulties have been encountered, and the subgroup on sheep and goat development (1973) recommended that the full use of "improved" crossbred wool in cottage industries should involve establishing service units in the villages for scouring and carding (with which there had been problems), developing intermediate technology for handling the improved wools, and training villagers in the use of the facilities.

We now have specifications of the commercial manufacturing requirements for apparel wool, thanks to the Australian Objective Measurement Project, and the New Zealanders are looking at specifications for carpet wools, but what is lacking is a clear statement of the requirements for hand processing. Since handicraft is likely to remain an industry, a clearer definition of requirements is needed.

White or pigmented sheep. One criterion originally laid down by the Government of India had to be reassessed. With the aim of producing wool for commercial mills, the Government's original stipulation in improvement programmes was that only white crossbred rams should be distributed. Not only are many of the sheep in the south pigmented, but the farmers have a preference for pigmented animals. Tradition says the pigmented animals are hardier than the white, and the ewes have more lambs. Further, most of the wool is used in cottage industries, making blankets or clothing for home use and carpets for sale; pigmented wool saves dyeing costs. In 1975, relaxation of the requirement for white rams was recommended as far as the southern states were concerned.

Rate of spread of exotic genes

The following are results of a numerical exercise in relation to the Indo-Australian Project for introducing Corriedales. Similar exercises could be done with different basic assumptions, but those set out below relate to the Indian scene:

- Additive gene action for production characters.
- A central stud of 3 000 exotic breeding ewes, with an annual output of 500 rams for distribution.
- A total of 12 000 ewes, initially indigenous, in multiplying units producing crossbred rams for distribution to farms.

- A number of village flocks, each with 50 ewes, using one ram for natural service, or one tenth of a ram for artificial insemination. (This figure of 50 is above the original definition of 30 ewes or less for smallholders. One could assume grouping of smaller flocks for mating. If this could not be done, the time of spread would be longer for natural service, but unchanged with artificial insemination.)
- The following vital statistics:

  Ewe life: five years (purebreds) or six years (indigenous and crossbreds)
  Ram life: three years
  First mating: 1½ years
  70 lambs born per 100 ewes joined with natural service
  60 lambs born per 100 ewes joined with artificial insemination
  Deaths from birth to 1½ years:
  — 10 percent lambs from purebred indigenous ewes
  — 20 percent lambs from exotic ewes
  — 12 percent lambs from crossbred ewes

Two points are of interest in the calculations: how many ewes in village flocks can be influenced within a given time span? And what will be the average level of exotic genes over all the flocks so influenced at the end of that time span?

We have a central stud, and multiplying units to produce crossbreds. What level of crossbred rams should be used? Probably we would start with 50 percent, and rise to 75 percent.

Assuming that exotic rams surplus to the requirements of the multiplying units can be used by artificial insemination in village flocks, then in 10 years, 1.4 million ewes will be influenced in village flocks (about 2/3 by purebred rams); in 20 years, the number will be 2.8 million [1]. The levels of exotic genes reached will be as shown below (in percent):

	Pure then 3/4	*3/4 then ½*
10 years	36	20
20 years	53	33

[1] These calculations have been set out fully in H.N. Turner, R.H. Watson and C.S. McKay, 1975, *Report on the Hissar Project*, Vol. 2, Australian Development Assistance Agency, and in H.N. Turner, 1976, *Proceedings of the International Sheep Breeding Congress*, Muresk, Western Australia.

Remembering that the aim is to reach 50 percent, the process is slow.

Selection methods for smallholders

Selection within a flock is impossible and there are two main alternatives: distribution from central studs of superior rams obtained by selection within a breed; and the establishment of cooperative breeding schemes among the smallholders themselves. This can be combined with "rings" of such cooperatives, with circulation of rams to minimize inbreeding.

Comparison of gains from selection with those from crossbreeding

In 10 years production levels for a breeding flock are given by:

Selection: Base + $4.0\Delta Ga$

Crossing: Base + $0.6c$ (allowing five initial years for testing)

where

ΔGa is the annual genetic gain, and

c is the difference between crossbred and indigenous breed.

Cumulated extra production in 10 years is:

Selection: $12\Delta Ga$

Crossing: $6.0c$

So a 50 percent cross will give as much extra production as selection only if:

$1.2c = 12\Delta Ga$, or

$c = 10\Delta Ga$

If $\Delta Ga = 2$ percent, as with wool, then $c = 20$ percent. Thus the exotic breed must be 40 percent above the indigenous *in the indigenous environment.*

Remember the length of time needed to reach 50 percent exotic in a whole population. In 10 years the average level of exotic genes, even starting with pure exotic rams, is only 36 percent, so the exotic breed would need to be $20 \times \frac{100}{36}$ = approximately 60 percent above the indigenous for equal extra production, not $20 \times \frac{100}{50}$ as in the case of halfbreds.

Selection can, of course, be added to crossing. If we assume the same ΔGa, starting from year 8, i.e., after the trial period and the first entry of selected animals into the breeding flock, then in year 10 the cumulated gain in the crossbred flock is $1.2c + 1.2\Delta Ga$ and we have:

$$12\Delta Ga = 1.2c + 1.2\Delta Ga, \text{ or}$$

$$10.8\Delta Ga = 1.2c$$

$$c = 9\Delta Ga$$

One more point is worth making — selection can be done simultaneously at many centres, while crossing is limited by the number of exotic males.

It is not suggested that one should automatically conclude that selection will be superior to crossing, but rather one should look at comparisons such as those outlined in order to make a rational decision. No amount of selection will turn a Deccani into a fine-wool; and if a fine-wool is wanted, perhaps a cross is a start. But will it be successful? If sheep with over 50 percent exotic genes will not thrive (as suggested by various Indian committees), what use can be made of wool from sheep with 50 percent exotic genes or less? May it turn out to be suitable neither for commercial mills nor for cottage industries?

In this presentation, we have been concerned mainly about wool. Let us consider meat for a moment. High fecundity is a precious genetic resource. If the sheep with high fecundity are small, why not keep the ewes as they are, and gain size in the lamb by the choice of sire? This can be done even in small flocks of indigenous ewes by alternating matings of indigenous rams (for replacements) with terminal sires (to produce lambs for slaughter). Depending on the actual level of lambing percentage, the matings need not be 1:1. Replacement ewes might need to enter the flock only every third year (or third mating, if more than one a year) instead of every second.

Again, with a cooperative scheme, it should be possible to have replacements every year by cooperators taking it in turns to supply them. ■

The halothane test, a new selection tool in pig breeding

G. Eikelenboom, D. Minkema and W. Sybesma

Exactly 25 years have gone by since the first report of Ludvigsen (1953) on the condition that later became known as pale, soft, exudative (PSE) pork (Briskey, 1964). Much research has been devoted to the problem since then [reviewed by Cassens, Marple and Eikelenboom (1975)].

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For more than ten years the condition was considered to be confined to the post-mortem period, before it became evident that it was related to an abnormal physiology of the live animal. Elevated serum enzyme activities and higher body temperatures were observed prior to slaughter in pigs which later showed PSE (Sybesma and Van Logtestijn, 1966; Sybesma and Hessel-de Heer, 1967).

It was then shown in Pietrain pigs that a complex of symptoms largely similar to those which in post-mortem give rise to PSE may occur in the live animal during conditions of stress. When this complex of symptoms, known as "Porcine Stress Syndrome" (Topel *et al.*, 1968) or the "Malignant Hyperthermia Syndrome" (Sybesma and Eikelenboom, 1969), was sufficiently serious, it appeared to give rise to mortality in certain pigs that were stress-susceptible. It was also demonstrated that the syndrome could be triggered in these animals not only

Reaction to halothane in a stress-susceptible pig: muscle rigidity and spasms. (Credit: H. de Vries)

by stress but also by allowing them to breathe the anaesthetic halothane (Sybesma and Eikelenboom, 1969; Allen *et al.*, 1970).

Genetic studies on PSE indicated a moderate heritability of various post-mortem muscle quality traits (Weniger, Steinhauf and Glodek, 1970; Walstra *et al.*, 1971). Consequently, research efforts have focused on developing methods to predict stress-susceptibility and to measure the PSE syndrome in the live animal, for possible use as selection criteria in a breeding programme.

Among the methods suggested were measurement of muscle biopsy metabolite levels (Schmidt, Zuidam and Sybesma, 1972) and certain serum enzyme activities in pigs after they have been exposed to standardized stress conditions (Richter, Flock and Bickhardt, 1973). However, a major breakthrough occurred when it was discovered that it was possible to identify stress-susceptibility in young pigs by allowing them to breathe halothane, without a lethal development of the malignant hyperthermia syndrome (L. L. Christian, 1973 — personal communication; Eikelenboom and Minkema, 1974; Ollivier, Sellier and Monin, 1975).

This article describes some of the results obtained with the halothane test so far, and looks at some possible applications in pig breeding programmes.

Reaction to halothane in a non-susceptible pig: muscle relaxation. (Credit: H. de Vries)

Halothane test

In the test procedure currently applied at the Schoonoord Institute, 6- to 12-week-old pigs are restrained and allowed to breathe a mixture of oxygen (2.5 l/min) and 5 percent halothane through a face mask. When the animal develops a progressive muscle rigidity and spasm it is termed a "reactor", "positive" or "stress-susceptible". As soon as this symptom is observed the application of the anaesthetic is stopped, after which the animal recovers within a few minutes.

In "non-reactors", "negative" or "stress-resistant" pigs, the onset of anaesthesia coincides with complete muscle relaxation (see photographs). In such animals, the test duration is four minutes.

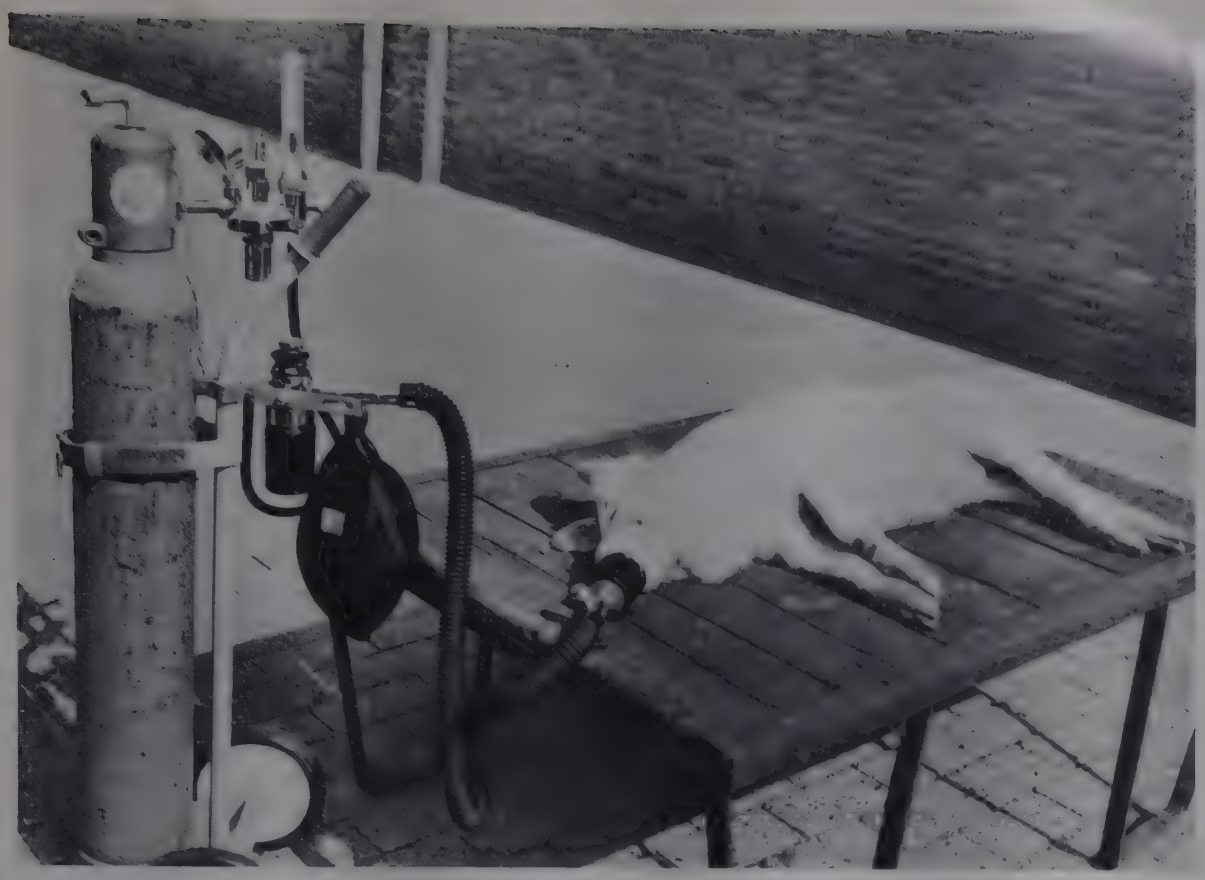
In preliminary studies involving a total of 690 young Dutch Landrace pigs from the Institute's experimental herd, it was found that reactors possessed inferior meat quality, lower backfat thickness, carcass length and slaughter loss, and higher ham, shoulder, and total meat percentages and meat-to-bone ratios compared with non-reactors. A slower growth rate was found in reactors owing to their lower feed intake, under *ad libitum* conditions. However, no significant difference in growth rate was observed between reactors and non-reactors under restricted feeding conditions (Eikelenboom and Minkema, 1974; Van Eldik, 1975).

Studies have indicated that the malignant hyperthermia syndrome is inherited as a single autosomal recessive gene with high (Ollivier, Sellier and Monin, 1975; Smith and Bampton, 1977) or complete (Minkema, Eikelenboom and Van Eldik, 1977a) penetrance. Such an inheritance pattern means that a reactor is a homozygote and a non-reactor is a carrier (heterozygote) or a non-carrier (homozygote).

The preliminary results obtained with the test were so promising that it was decided to investigate its application as a routine procedure at a testing station.

During a one-year survey (Eikelenboom *et al.*, 1978) at one of the Dutch national testing stations a total of 2 956 pigs were tested, comprising 1 304 Dutch Yorkshire, 1 640 Dutch Landrace and 12 Belgian Landrace pigs. The percentage of animals that reacted positively to the test was found to be relatively low (3.1 percent) in the Dutch Yorkshire. In the Dutch Landrace, however, the percentage of reactors was much higher (22.2 percent), while all 12 Belgian Landrace pigs reacted positively to the test. Only two pigs died as a consequence of the test, representing 0.68 per thousand of the total tested. However, Ollivier, Sellier and Monin (1977) and Webb (1978) reported higher losses due to testing.

Losses among both sexes during the fattening period were 1.92 percent and 0.24 percent in reactor and non-reactor Dutch Landrace pigs respectively. During the transport of the gilts to the slaughterhouse 3.35 percent of the reactors and 0.32 percent of the non-reactors died. Thus, total losses in the Landrace pigs were almost ten times higher in reactors than in non-reactors. Webb (1978) found an incidence of sudden deaths of 11 per-



Simple anaesthesia apparatus used for the halothane test. (Credit: H. de Vries)

cent in reactors and 1 percent in non-reactors, excluding those directly attributable to the test itself.

Differences in growth rate between reactors and non-reactors were only minor, but ultrasonically measured backfat thicknesses were clearly smaller in reactors than in non-reactors. Clear differences between the two categories of animals were found in the meat and carcass quality traits, which are listed for the Landrace gilts in Table 1. As in the preliminary experiments, reactors showed lower slaughterloss, less backfat and a higher ham and loin percentage than non-reactors. The meat quality of the reactors was inferior to that of non-reactors, as indicated by the results of both the subjective evaluation and the objective laboratory test for the transmission value (protein solubility).

The hereditary basis of the malignant hyperthermia trait is clearly illustrated in the second phase of these investigations, which was recently concluded. Table 2 illustrates the difference in percentage of reactors found among offspring of reactor and non-reactor Dutch Landrace boars used for artificial insemination, which were tested during the first phase of these studies. Reactor boars have almost twice as many reactors among their offspring as do non-reactor boars.

TABLE 1. **Carcass and meat quality traits in Dutch Landrace gilts classified as reactors (R) and non-reactors (NR) to halothane**

	R	NR [1]
Number of gilts	166	608
Slaughter loss (%)	22.0	22.8
Carcass length (cm)	83.1	84.0
Av. backfat thickness (mm)	23.1	23.9
Ham (%)	27.6	26.7
Loin (%)	20.1	19.7
Meat quality score (scale 4-8)	5.5	6.8
Transmission value	50	29

[1] $P < 0.001$ for all items in this column.

TABLE 2. **Test results in the offspring of halothane reactor (R) and non-reactor (NR) Dutch Landrace A.I. boars**

Type of boar	Number of boars	Number of offspring investigated	Reactors (%)
R	7	300	40.7
NR	31	1 310	21.3

Application of the halothane test as a selection criterion

Two recent symposia were partially devoted to PSE and sudden death among pigs, and presented a good opportunity to compare the breed incidence of halothane-reactors in various countries.

In general, the Duroc and Large White breeds appeared to be stress-resistant and there was a low incidence of reactors in Yorkshire and Hampshire pigs. The incidence in samples of the Landrace breed varied between 4 percent (Norwegian Landrace) and 85 percent (Belgian Landrace) in the various countries. Incidence of up to 94 percent was noted in the Pietrain breed.

Ollivier, Sellier and Monin (1977) found significant differences in muscular development in favour of the reactors, as judged at weaning time, and suggested that selection on the basis of muscular development might have caused the high incidence of reactors in certain breeds. However, even when selection is performed with an index, the disadvantages of a poorer meat quality in reactors are, in general, outweighed by the higher meat percentage and lower backfat. Consequently, the selection index will be higher for reactor boars than for non-reactors.

Studies with mathematical models (Cöp, Minkema and Eikelenboom, 1977) showed that when there is no selection against reactors, their percentage in the population will increase in spite of the higher losses among reactor animals. However, it is these losses in particular which force one to select against reactor animals in the Dutch Landrace breed. The mortality rate found in the experiments resulted in an estimated loss of US$4.80 (Dfl. 11.00) per reactor compared with non-reactors (Minkema *et al.*, 1977b).

With direct selection against the trait, the gene frequency will decrease. The effect is dependent on the selection method applied (selection in one or both sexes) and the way the gene affects other correlated production traits such as meat quality and meatiness. It is not yet known if this influence is additive or recessive; in

other words, if the carrier and non-carrier are different or equal for these traits. In the first case, carriers will have a selection advantage over non-carriers and consequently the selection response will be lower.

Assuming such an additive influence of the gene on the correlated traits and when selection is only in boars, the present figure of approximately 25 percent of reactor animals in the Dutch Landrace breed will probably decrease to 7 percent or lower in as little as five generations of selection (Minkema *et al.*, 1977b). Ultimately, an equilibrium will be reached in which only 1-2 percent of the animals are still reactors. When there are 4 percent or fewer reactors the exclusion of carrier boars could be considered on the basis of the test results of their offspring. This is not possible at the moment, since too many boars would be excluded.

The reactor boars that are excluded can still be used for breeding. By making a single cross with Yorkshire sows, they may serve for the production of fattening pigs. The fattening pigs produced are predominantly non-reactors because of the low incidence of reactors found in the Yorkshire breed and because of the recessive nature of the trait.

Another attractive possibility is to develop a non-carrier sow line. Based predominantly on the previously reported breed differences it is suspected that the reproduction of reactor sows is inferior to that of non-reactor sows. In fact, Webb (1978) found that non-reactors produced an average of as much as 1.16 piglets per litter more at parturition than reactors. With a specially developed sow line of non-carriers, a terminal cross can be made with a boar line consisting of reactor animals, selected for superior meatiness, for the production of fattening pigs. These fattening pigs will be non-reactors and yet will have good carcass quality, provided the latter trait is additively inherited.

The results of these investigations have led to the development of the halothane test routinely used for the Dutch Landrace pigs sent to Dutch testing stations. Reactor boars are no longer used for artificial insemination. In addition a number of private breeding companies have incorporated the test in their selection programmes.

There is no doubt that within 25 years of Ludvigsen's report (1953) on what was then called "muscular degeneration" in hogs, considerable progress has been made in research efforts to improve stress-resistance and achieve an optimum combination of carcass and meat quality characteristics in the modern meat-type pig. ■

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Outbreak of duck plague in Thailand

B. Tóth and V. Suwathanaviroj

During 1976 and 1977 duck plague (DP) broke out in Thailand for the first time and caused severe losses in the poultry industry. The Thai Veterinary Services, with the help of the Netherlands Government and FAO, succeeded in bringing the disease under control and in stopping any further spread. This article contains a short description of the outbreak, the main conclusions to be drawn and some recommendations for dealing with the disease.

Duck breeding in Thailand and in some other countries of Southeast Asia is of great importance in supplying the population with meat and eggs. About 65 percent of the world's duck population is to be found in Asia, with Thailand having a duck population of about 20 million, Viet Nam about 40 million and Indonesia about 14 million. Duck eggs and duck meat constitute one of the most preferred items in the diet of the Thai people. The per caput consumption of duck eggs in Thailand is estimated to be about 60 eggs per year.

Traditional duck rearing has been undertaken in this part of the world for many centuries and the large number of canals, rice fields, rivulets and ponds lend themselves well to duck rearing. Using traditional methods of duck management and feeding, Thailand has developed a simple, industrial-scale system well adapted to local conditions. In local market conditions the products of this duck industry compare well with those of the modern poultry industry.

For the most part local duck breeds of a laying type are raised, *viz.*, Nakhon Pathom and Paknam. The imported Khaki Campbell breed has been used to upgrade local ducks.

Most day-old stock comes from hatcheries and there are still a few in existence which use only solar energy for hatching chicken and duck eggs, based on the old Chinese hatching method. After the day-old ducklings are sexed, the females are sold as breeders or layers and the males are raised as meat ducks. These two groups are raised separately, usually in rice fields or other free-range systems until they are three to four months of age. The drakes are then fattened for a period of two to three weeks and slaughtered and the females are removed to laying farms.

Duck rearing takes place mainly near the sea and riverine areas or close to canals and ponds, but some rearing in dry land areas is also practised. Duck rearing is the main occupation of many farmers, who can obtain appreciable returns from keeping 500-600 laying ducks. Most of the ducks in Thailand are kept on small or medium-size farms (under 2 000 or between 2 000 and 20 000 ducks); a few large duck farms raise 20 000-200 000 ducks.

Ducks are generally kept in simple, home-made sheds consisting of a fenced area with a thatched roof. The floor is made of clay and the ducks are kept on deep litter throughout their lifetime, the manure being used as fertilizer. Even large farms are not mechanized, except for a feed mincer.

The feed consists of rice bran, broken rice (sometimes cooked) and fresh fish offal, mixed with salt. Premix or compound feed is not used.

The course of the epizootic

In September 1976 a disease hitherto unknown in Thailand broke out in Chachoengsao Province, in one of the most densely duck-populated areas. The outbreak occurred in a village located along the banks of a large canal to which the ducks had access. The first outbreak was observed at the southern end of the village in a White Pekin duck farm. Usually the water in the canal flows from the north to the south, but during high tides it reverses direction. The village had 108 duck farms, with a total of more than 200 000 laying ducks. Within two months 80 percent of the farms were infected and 78 to 100 percent

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mortality had occurred on the infected farms (Suwathanaviroj *et al.*, 1977).

The origin of the infection is not known, but it is likely that migrating wild birds were the source as this was the migrating season. It is known from the literature that duck plague has occurred in China and in 1975 in India.

A preliminary diagnosis of duck plague was suggested by the Department of Livestock Development (the responsible Government agency) early in the outbreak, but this diagnosis was disputed by some local experts. Some stated that the disease was similar but not identical to duck plague (Tanasugarn, 1977); others claimed that it was fowl cholera. The isolation and identification of the causative virus have subsequently proved that the disease was duck plague (Suwathanaviroj *et al.*, 1977; Tantaswasdi 1977). At the end of November 1976, this finding was also confirmed by experts from the Netherlands (Yadin, 1977).

At the beginning of the epizootic, in October and November 1976, no statutory measures were implemented nor was vaccination applied, with the result that the disease spread rapidly to other villages and to neighbouring provinces, which also had large duck populations. The high losses that occurred created serious alarm among duck owners, who — to avoid still bigger losses — started to slaughter and sell their flocks. Many sick and dead birds were sold, and in this way the disease became even more widespread. As the farms are not isolated from each other, the spread of the agent was promoted by the movement of personnel as well as by the marketing of eggs, feed and manure.

By the end of November 1976 six provinces were infected — all around Bangkok, the most densely duck-populated areas. The table shows the further spread of the disease, while Figure 1 illustrates the geographic and chronological distribution in the infected provinces. It also indicates the duck population of each province. Of the 71 provinces 29 were infected, mainly those with the densest duck populations. The figure also shows that the duck industry is concentrated near the sea where fish offal is abun-

Figure 1 *The geographic distribution of infected provinces. The duck populations (in thousands) are shown for each province.*

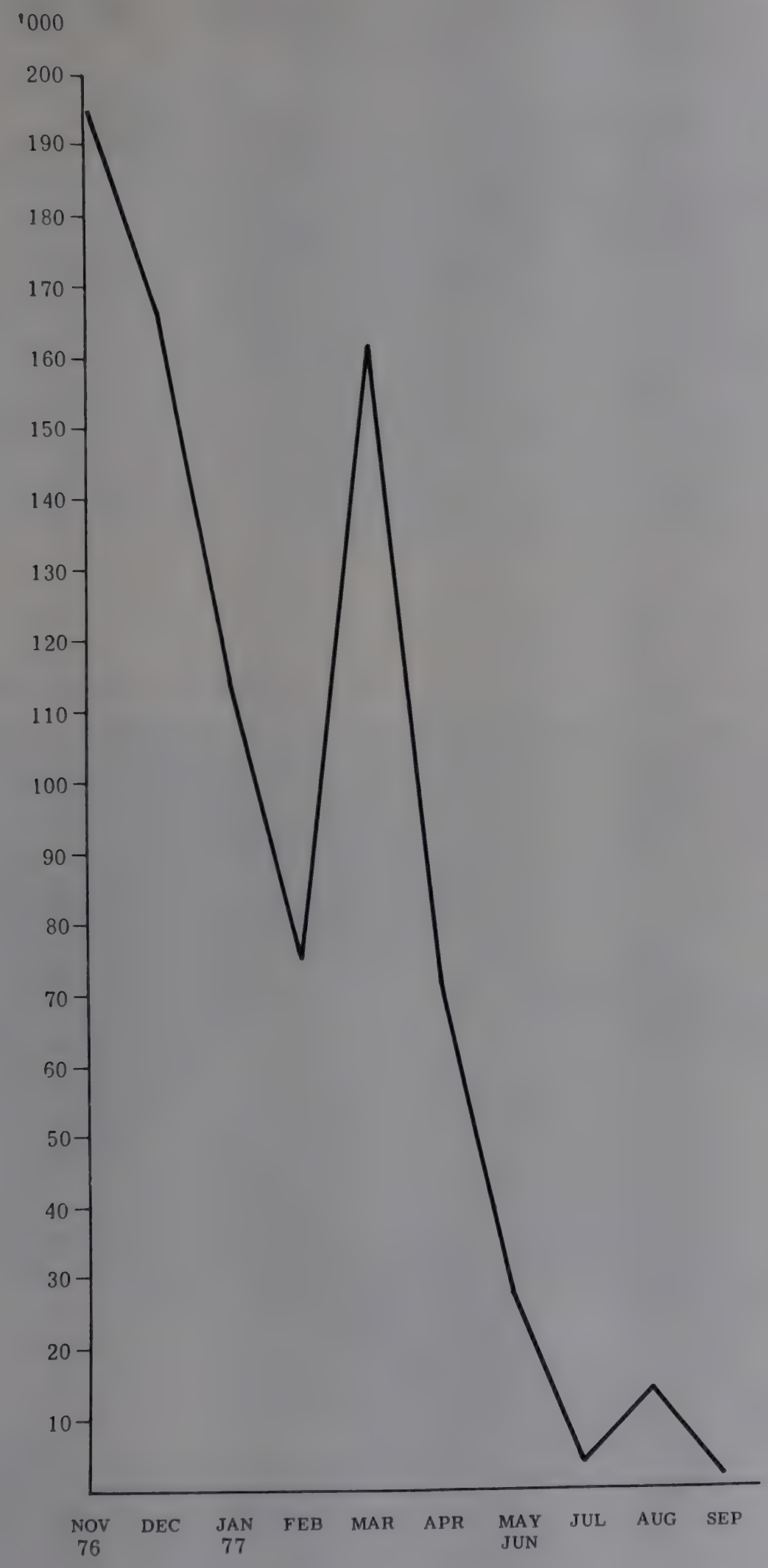

Figure 2 *Mortality from duck plague in Thailand from November 1976 to September 1977.*

dant, and on the large irrigated plains.

Figure 2 shows the total mortality caused by duck plague during the period November 1976 to September 1977, based on the official reports of the District Veterinary Officers.

Figures 1 and 2 show two peaks in the curve of the DP epizootic: one in November-December and the other in March-April. The first illustrates the very rapid spread of the disease at the beginning of the outbreak, when neither legislative measures nor vaccination had been introduced. Mass vaccination started in January, and its favourable effect may be seen in the marked decrease in mortality in January and February. The second peak reflects the sharp increase of mortality in March and April, due mainly to the spread of the disease to 13 new provinces. In some of these the disease was reported and diagnosed too late, and therefore the disease spread before control measures could be implemented. The rapid spread of the plague caused a temporary shortage of vaccine, so vaccinations could not always precede the spread of the virus, and sometimes only followed it. Thailand did not yet have a large enough stock of vaccine and local vaccine production was sufficient only for everyday needs.

It may be seen from Figures 1 and 2 that the duration of the "malignant" epizootic, connected with high losses and rapid spread of the disease, was seven months, from October 1976 to April 1977.

Clinical characteristics

Laboratory examinations carried out locally and in the Netherlands, as well as field observations, have shown that the virus causing the epizootic was highly virulent. Ducklings experimentally inoculated with it died within two or three days, with typical lesions. Cross-neutralization tests showed that the Thai DP virus was antigenically identical with earlier isolated viruses.

Domestic ducks, and in one case geese, were reported to have contracted the disease.

The mortality rate during the whole period of the epizootic was also high

in susceptible ducks, averaging [illegible] percent. There was no difference in the susceptibility of the different breeds of ducks. Ten days was the youngest age at which ducklings contracted the disease. No great difference existed in the susceptibility of different age groups, sexes or functional types. For example, layers of all ages before and after the onset of laying were equally susceptible.

An observation made in March 1978 indicated that the mortality rate toward the end of the epizootic decreased significantly. In two laying flocks in close proximity, natural infection caused only low mortality. Flock No. 1, which was 8 months old and consisted of 1 000 birds, had 10 percent mortality in 2 weeks, while Flock No. 2 had only 0.3 percent. When the flocks were vaccinated mortality stopped. The date of the earlier

Number of infected provinces in the period November 1976 - December 1977

Time	Number of newly infected provinces	Cumulative number of infected provinces	Number of provinces reporting mortality from DP
November 1976	6	6	6
December 1976	2	8	8
January 1977	6	14	14
February 1977	1	15	14
March 1977	6	21	19
April 1977	7	28	24
May, June 1977	1	29	18
July 1977	0	29	2
August 1977	0	29	3
September 1977	0	29	3
October 1977	0	29	3
November 1977	0	29	2
December 1977	0	29	1

Figure 3 *Haemorrhages and macular diphtheritic pseudomembranes along the longitudinal folds of the lower third of the oesophagus.*

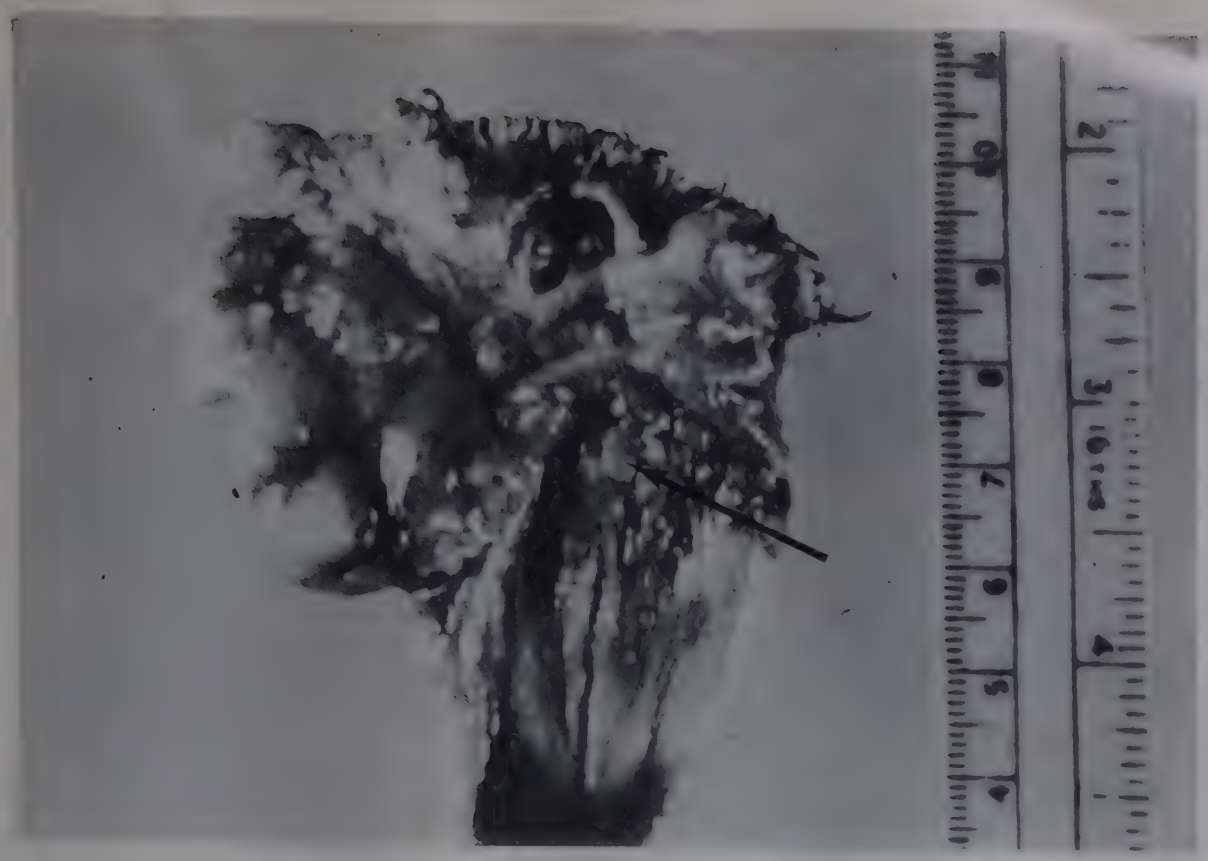

Figure 4 *Cloacal lesion marked with an arrow.*

vaccination of Flock No. 1 is uncertain, since the owner had purchased them at five months of age. Flock No. 2 had been vaccinated eight months earlier. Egg production in Flock No. 1 dropped from 80 to 60 percent during the infection.

One of the most striking clinical characteristics in the duck plague syndrome was that the sick ducks could not move — they appeared to have paralysis of the legs. It should be emphasized that the post-mortem lesions observed were sometimes very similar to those of fowl cholera. The oesophagus and cloaca should always be checked for differentiation. Duck plague caused the following pathological changes in these two organs: petechial haemorrhages or diphtheritic macular pseudomembranes along the longitudinal folds of the oesophagus (see Figure 3). In the cloaca and sometimes in the neighbouring parts of the bursa of Fabricius, salpinx, caecum and rectum, ecchymotic haemorrhages or macular pseudomembranes can be found (see Figure 4).

Mode of spread

At no time during the whole epizootic was it observed that the disease was spread by hatcheries or by egg transmission.

The first outbreak in the country was observed in a flock having access to water. Water was an important factor in the spread of the virus. However, when the disease became enzootic in a particular area, another important way of spreading the virus was the traffic in sick and dead birds.

At the beginning of the epizootic, when control regulations had still not been issued by the Government, many farmers sold their sick and dead ducks. At that time this was perhaps the most important factor in the spread of the disease.

Infected manure could also spread the disease; for example, in one case the infection was introduced into a disease-free province by means of an infected manure boat belonging to a farmer about 200 km distant. In another case DP broke out in a flock kept on deep litter, infected three months earlier, when the manure was spread.

Some observations indicate that fomites, such as feed sacks, vehicles, and crates, were not important in spreading the infection. For example, in Chon Buri it was observed that lorries carrying fresh fish offal from farm to farm did not spread the disease.

During the epizootic it was also noticed that the DP virus had only a limited potential for spreading. The spreading tendency of the virus is not as high as that of, for example, Newcastle disease, infectious bronchitis or Marek's disease viruses. In the village where the first outbreak occurred, where all the farms were located on the side of a canal, and farms were close to each other, only 80 percent of the farms became infected. In the town of Chon Buri, which has the largest duck population in Thailand, only about 15 percent of the farms contracted the disease.

Toward the end of 1977 it was noticed that the virulent virus had disappeared from many of the earlier heavily infected flocks. For example, one large fattening farm had always kept more than 60 000 ducks (meat ducks and layers) on the same farm. Every week the farm received thousands of meat ducks from different farms and, after two to three weeks of fattening, these were slaughtered. This continuous rotation resulted in a high level of infection being maintained from January to December 1977. Since then, however, no deaths due to DP have been observed on this farm.

On two farms the persistence of DP infection was checked by using susceptible 3-week-old "sentinel" ducklings. Ten sentinels were put in a flock of 1 800 layers, in which mortality due to DP had occurred one month earlier. During the one-month observation period the sentinels remained healthy. The same result was obtained on another farm.

All three cases indicate that the virulent virus infection — under the influence of unknown factors — can disappear from some flocks or can become attenuated after a certain period, and will not persist in all flocks.

Control measures

When the first outbreak of DP occurred, there was no veterinary legislation covering the control of the disease since it had not, until then, appeared in the country. When the diagnosis of the disease was officially accepted, the Department of Livestock Development issued an explanatory leaflet to all District Veterinary Officers (DVOs). The leaflet described the

Figure 5 *Vaccination of ducks against duck plague with an automatic syringe.*

first outbreak of DP, the most important symptoms, pathological changes and prevention and control measures. Later, DP was officially declared to be a notifiable disease.

Although these veterinary orders played an important part in the campaign against DP, vaccination was the most important method in controlling the disease (see Figure 5) and the Government decided to make vaccine available free to farmers. All vaccinations were carried out by the local DVOs. Initially, because of a shortage of vaccine, farmers were able to have their flocks vaccinated only if the DVO had diagnosed DP in their flock. Later, flocks in the neighbourhood of infected flocks were also vaccinated. Practical experience shows that in the case of DP it is unnecessary to vaccinate large areas prophylactically, i.e., to undertake extensive ring vaccination, except where there is a strong possibility that the virus will spread through canals, ponds, etc.

Vaccination proved to be very effective. In most infected flocks mortality ceased seven to eight days after vaccination. When two vaccinations were given to ducks over three months of age, the immunity lasted at least six months. In such cases a 90 to 95 percent protection developed in most of the flocks.

Cases of breakdown of vaccine-induced immunity were reported and examined. Breakdowns were reported more than one to two months after

vaccination; if the birds had been vaccinated only once, breakdowns also occurred during this period. In many cases of apparent breakdown, it was found that the disease was not DP but fowl cholera. Another important result of these examinations was that if birds were vaccinated under three months of age when their immune competence was still not complete, they developed a low level of protection. For example, on a large fattening farm, drakes were vaccinated three times: first at 2-3 weeks, second at 6-7 weeks and third at 10-11 weeks of age, but this did not prevent losses. During the 2- to 3-week fattening period 10-30 percent losses occurred in meat ducks. On the same farm, however, among the laying flocks, which were kept in the same highly infected surroundings, losses were only the normal 1 percent per month. It can be concluded from the above observation that vaccinated or revaccinated ducks that are over three months of age develop solid immunity.

For layer or breeder ducks kept in infected or exposed surroundings the following programme was suggested: first vaccination at three weeks of age, second vaccination at three to four months, and revaccination every six months. Vaccination prior to two weeks of age interferes with maternal immunity and should be avoided.

The first 500 000 doses of vaccine were imported from the Netherlands. Local vaccine production — with the help of the Netherlands Government and FAO — was organized quickly. The first batch of vaccine was produced on 9 December 1976 at the Veterinary Biological Laboratories in Pakchong. In one year the Laboratories produced more than 21 million doses of vaccine, most of which was used.

The vaccine was an attenuated live virus, cultivated in hen eggs. It was in liquid form, and was kept frozen until used in the field. In 1978 the laboratories in Pakchong, with the help of FAO, started to produce tissue-culture freeze-dried vaccine, which has better keeping qualities — a very important factor under tropical conditions.

Finally, it should be emphasized again that, in the duck-keeping conditions of Thailand, vaccination was the most important and most effective method of control. Precautions should now be taken against future outbreaks of DP and at least five million doses of lyophilized vaccine should be held ready for immediate use. Other countries in Southeast Asia also have large duck populations which could be endangered by this disease. Since no country in the world keeps sizeable stores of vaccine, the suggestion to establish a vaccine bank for this disease seems all the more important.

Based on the experiences gained in Thailand, the most important recommendations for the control of DP are summarized below.

Diagnosis. Characteristic lesions of DP are found in the oesophagus and the cloaca. Along the longitudinal folds of the oesophagus, petechial haemorrhages or diphtheritic macular pseudomembranes are typical indications of DP. In the cloaca and sometimes in the neighbouring parts of the bursa of Fabricius, salpinx, caecum and rectum, ecchymotic haemorrhages or diphtheritic macular pseudomembranes also indicate DP.

Histologically intranuclear inclusion bodies are present in the affected cells.

At the first outbreak of the disease or in suspected cases, it is necessary to confirm the diagnosis by virus isolation and identification. For DP virus isolation, 10- to 12-day-old embryonating duck eggs are inoculated on the chorioallantoic membrane with a 20 percent liver suspension from infected ducks. The embryos dying at 2-7 days inoculation show extensive haemorrhages. The isolated virus should be identified by the neutralization test with DP anti-serum of known potency.

Control. Countries that have a large duck population and that are threatened by or suffer losses from DP should include DP in their veterinary law as a notifiable disease.

The importation of ducks or duck eggs should be allowed only from areas that — according to an official veterinary statement — are free from DP.

Suspicious disease or cases of death in duck flocks should be reported immediately to the veterinary services. No medicaments or drugs are available to treat sick or infected birds, but non-infected ducks can be protected very effectively against the disease by vaccination. All ducks and geese exposed to infection, infected flocks, and neighbouring farms should be vaccinated immediately after the detection of DP. Duck flocks exposed to DP infection should be kept enclosed on dry land.

Infected flocks should be quarantined. Personnel movement should be restricted. The removal of infected, sick or dead ducks, infected tools, and manure should be prohibited. Carcasses should be destroyed and when mortality ceases a thorough disinfection of the premises should be carried out. As soon as it is economically feasible the whole flock should be slaughtered for meat. The new flock should be introduced only after a repeated disinfection of the premises.

Vaccine production. In countries where duck-keeping is economically important and where DP is enzootic, it is recommended that they establish their own vaccine production. Under simple laboratory conditions the production of attenuated living DP vaccine of chicken embryo origin is suggested.

Where the laboratory conditions are suitable for tissue-culture techniques and lyophilization, the introduction of tissue-culture freeze-dried vaccine is recommended. ■

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Ticks and tick-borne diseases as a barrier to the introduction of exotic cattle to the tropics

L.L. Callow

For many years ticks have taken a toll of exotic cattle (*Bos taurus*) introduced to tropical and subtropical developing countries. The most obvious effect of ticks has been as vectors of disease. The four conditions most responsible for loss are theileriosis, babesiosis, anaplasmosis and heartwater (*Cowdria ruminantium*) infection. A number of tick genera including *Boophilus, Amblyomma* and *Hyalomma* have pathological effects independent of their roles as vectors. The problem has been considered and some efforts at control made in North Africa (Sergent *et al.*, 1945), Taiwan Province of China (Otte and Kiltz, 1968), Trinidad (Williams and Gonzalez, 1968), West Malaysia (Rajamanickam, 1970), Sri Lanka (Ranatunga and Wanduragala, 1972), India (Menon, 1974) and Bolivia (McCosker, 1975).

In recent years, interest in crossbreeding and demand for exotic cattle in developing countries have increased. In catering for this demand, some international and national bodies have underestimated the risks associated with the presence of pathogenic ticks in countries utilizing exotic cattle. This article is an analysis of causes of the currently high wastage of exotic cattle during and after importation to some countries, and also contains recommendations for reducing the loss. Although much of its content is based on experience with cattle exported from Australia, the same problems undoubtedly exist in other regions.

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Choice of cattle

Exotic cattle are not always productive or healthy in the tropics because of poor adaptation to climate as well as to ticks and tick-borne diseases. Despite this, there is still a relatively uncontrolled flow of purebred animals from cool or even cold areas to equatorial and sub-equatorial regions. There are records of entire shipments of cattle dying, many shortly after importation, from disease and environmental stress. Attempts to introduce exotic blood in other ways are sometimes thwarted. Whereas artificial breeding is an admirable way of upgrading for production, the use of semen from a breed highly susceptible to an enzootic tick disease for which there is no vaccine or drug can have an undesirable effect. For example, *Bos taurus* × Sahiwal calves have died from theileriosis in Asia under circumstances in which a purebred Sahiwal might have survived.

Reasons for losses owing to breed unsuitability have to be defined. If climate is a limiting factor, there is no point in persisting with an exotic breed unless conditions are suitable for developing useful hybrid cattle. If climate is not a limiting factor, but tick diseases are a major hazard, these must be defined, and a decision made as to whether they can be controlled or not.

Production in a favourable environment still seems to be a major criterion for selection, despite the fact that a much more rigorous life awaits the animal in the tropics. Cattle selected in this way often fail to meet expectations. For example, the pro-

This 2-year-old heifer is the result of intelligently applied crossbreeding in a developing country.

duction of the champion cow of Tasmania (latitude 43°S) was reported to have fallen from "15 bottles a day to one bottle a day" on being exported to the tropics. A less impressive performer selected over several generations in subtropical, northern Australia (2 000-3 000 km closer to the equator than Tasmania and enzootic for *Boophilus*, babesiosis and anaplasmosis) may well have been a better choice.

Often pregnant females are chosen for importation, presumably to increase cattle numbers as rapidly as possible. This can have the opposite effect, as was illustrated recently when, following the export from Australia of 1 000 cows in advanced pregnancy, 400 died within weeks of reaching their destination after experiencing severe stress. A recent project to import reared Sahiwal cross calves about six months old into a second country should produce good results over a longer period of time.

Some countries have been importing poor-quality cattle. Cheap purchases are sometimes made of cattle culled for various reasons in their country of origin.

Losses inevitably occur among such cattle, and they provide a poor basis for any programme of livestock improvement.

Organization and preparation

Many groups and individuals play a role before contracts for supplying cattle to a developing country are fulfilled. They include major lending institutions based in developed countries, government departments in the importing country, and selling agents and the veterinary department of the exporting country. After the contract is determined, field veterinarians and finally the private suppliers of the cattle in the exporting country become involved.

With this cumbersome system, liaison is often poor, misunderstandings occur, and the operation suffers accordingly.

Problems in the exporting country. Some of the difficulties in the exporting country derive from insufficient time being allowed to fulfil contracts. The time available may be as little as four to six weeks, during which cattle are selected, sampled for health tests, tuberculin-tested, vaccinated, injected with antibiotic and sometimes moved from place to place before finally being gathered at a convenient holding-area prior to shipping. Even before the cattle are exported, they may suffer nutritional or other types of stress; and the mixing and crowding of a number of small groups while a consignment is being made up facilitate the spread of disease. There is seldom enough time to immunize susceptible cattle effectively against babesiosis and anaplasmosis, and sometimes vaccination is not performed at all.

A reason for the excessive activity and the short time available has been the existence of unrealistic health specifications. Cattle exported from Australia have had to be tested for contagious bovine pleuropneumonia, a disease that was eradicated there many years ago. Rigorous testing for dis-

eases that almost certainly have a higher incidence in the importing country than in the exporting country — such as brucellosis — is usually performed. One health requirement for a group of cattle leaving Australia several years ago was that they be free of babesiosis and anaplasmosis, despite the fact that their destination was hyperenzootic for these conditions. When high dosages of a sterilizing drug were given to these stressed, pregnant animals, 20 percent of the group died before leaving Australia. Reasonable liaison has since been established with the country concerned so that cattle to be imported are now vaccinated instead of given sterilizing drugs.

At the other extreme, too little regulation has been applied in certain regions, with cattle being allowed to cross borders, sometimes illegally and without health checks, spreading disease and in one known instance even introducing acaricide-resistant ticks to a country previously free of this pernicious problem.

Problems in the importing country. The factors governing the fate of cattle after export are complex. Obviously, the challenge they receive on arrival from *Theileria, Babesia, Anaplasma, Cowdria* or ticks *per se*, and the levels of pre-existing immunity the cattle possess against these parasites will have a major effect, even if in other respects the cattle are suitable for the new environment. Let us look now at the organizational deficiencies leading to stress and exacerbation of tick diseases.

Imported Hereford-zebu cross. Such animals require regular acaricidal treatment to control Boophilus microplus.

Poor timing. Most countries import cattle randomly throughout the year so that animals physiologically adapted to winter are frequently shipped to the northern hemisphere during that region's summer. Thus, cattle with long coats can leave Australia and be exposed within hours, if the shipment is by air, to very hot, humid conditions. Countries in the northern hemisphere should avoid importing cattle from Australia during the southern late autumn, winter and early spring and consider alternative sources in the northern hemisphere if cattle are urgently needed during this period. The same considerations, although covering a different period, apply to developing countries in the southern hemisphere that import cattle from North America and Europe.

Bad conditions on arrival. Some consignments of cattle are known to have encountered very adverse conditions on arrival in the importing country. These include inexpert handling while being unloaded, inadequate nutrition and the immediate strong challenge of one or more tick diseases while the cattle are still stressed from their journey. Good unloading facilities, and quarantine areas (e.g., sheds or open, well-grassed fields with shade shelters) that are kept tick free and large enough to accommodate importations should be available for the cattle on arrival. Cattle unfortunately sometimes contract babesiosis from ticks carried to them on cut pasture.

Lack of experience. Imported cattle suffer because of a lack of experienced personnel in developing countries. Inexperience leads to incorrect selection of cattle, the design of inappropriate health specifications, poor husbandry practices and ineffective disease investigation. In the last instance, there have been reports of losses due to babesiosis in cattle exported from Australia that cannot be rationally explained. An "outbreak" of babesiosis was stated to have occurred on a *Boophilus*-free island, and on another occasion in resistant Brahman-cross cattle originating in a hyperenzootic area of Australia and vaccinated before being exported. Small numbers of babesias or anaplasms are sometimes found in blood films taken from sick animals, even though babesiosis or anaplasmosis is not the primary cause of the disease. Misinterpretation of such findings in immunized cattle sometimes leads officials in developing countries to doubt the value of vaccination, jeopardizing the use of this worthwhile procedure.

Even when there has been good clinical evidence of tick-borne disease following importation of cattle, laboratory identification of the causative organism has on occasion been difficult to obtain owing to the lack of experience of personnel.

Prospects of controlling tick diseases

In considering control, diseases can be divided into three broad categories: those controllable by established immunological methods, providing these can be applied; those potentially controllable as a result of recent research; and those that are difficult to control in the tropics by chemicals or vaccines, but which, in certain cases, can be reduced in severity or avoided completely by management strategies. Before this discussion is developed it is necessary to reiterate the importance of defining which tick diseases are causing loss in a particular environment. This must precede any rational approach to control (Uilenberg, 1976).

Boophilus microplus *infestations, such as this one, killed 23 of 79 imported Hereford cows in a developing country.*

Controllable diseases. These include babesiosis and anaplasmosis. The principles of immunization have been known for 80 years, and efficient methods of vaccination were developed during the 1960s and 1970s (Callow, 1976). Effective drugs for treatment are also now available. The problems that remain are related to planning and organization. Appropriate vaccines are available or can be produced for susceptible cattle, even in a developing country (McCosker, 1975), but their effectiveness depends on how they are used. Immunization against an expected, strong challenge takes up to three months, and should be performed in the exporting country if possible. The procedures can be carried out in a quarantine area in the importing country, but problems of supplying and using vaccine and the risk that tick quarantine will break down make the first alternative preferable. The period required for immunization may be reduced if cattle are selected from areas enzootic for babesiosis and anaplasmosis, in which case they are likely to be at least partially immune.

Potentially controllable diseases. Theileriosis due to *Theileria annulata* and *T. parva* has always presented a formidable barrier to the successful importation of exotic cattle into parts of Asia and Africa, although blood vaccines were useful against *T. annulata* in North Africa and the Near East (Pipano, 1974), and vector control with acaricides protects some cattle against *T. parva*. Recently, cultured *T. annulata* has been successfully used for vaccination (Hashemi-Fesharki and Shad-Del, 1973; Pipano, 1974), and research into alternative methods of immunization is encouraging (Gill *et al.*, 1977). At the same time much progress has been made toward producing a vaccine against *T. parva* (Cunningham, 1977), which should eventually become available. Unfortunately, until vaccination against theileriosis is well established, exotic cattle being introduced to enzootic areas will continue to die in large numbers.

Diseases that are difficult to control. Disease caused by ticks *per se*, often underestimated in developing countries, is the least likely to be controllable by chemical or immunological means in the future. The effectiveness of acaricides can be expected to decline as ticks become tolerant to chemicals, and in some countries the increasingly high cost of dips and sprays will militate against their continued use. Biological control using tick-resistant cattle, especially *Bos indicus* breeds, should eventually succeed (Wharton, 1976), but the prospect is long-term, particularly for dairy cattle, and will depend on continuing endeavour by workers in animal production, breeding and parasitology in both developed and developing countries. In hot, humid regions some crossbred cattle with as high as 50 percent *Bos indicus* infusion suffer from heavy *B. microplus* infestations if not dipped regularly, and obviously these should be culled. Acaricide resistance in ticks, brought about by over-use of chemicals, has appeared in certain developing countries. The future for exotic cattle and a proportion of the crossbred animals dependent on chemical control appears bleak in such countries.

The possibility of eradicating ticks or holding populations at very low levels with minimal use of acaricides should be considered, although in developed countries eradication is usually rejected for economic and social reasons (Cattle Tick Control Commission, 1975). When acaricide resistance develops in a population of

A laboratory technician records rectal temperatures of cattle being immunized against babesiosis in Santa Cruz, Bolivia.

susceptible cattle in a tropical environment, this approach might have to be used as a last resort. Various forms of zero grazing, fairly common in some developing countries, lend themselves to the control of more than one tick species. The opportunity for keeping currently uninfested environments tick-free still exists in some countries where remote areas of virgin jungle are being cleared for cattle-raising. *B. microplus* was kept out of at least two ranches in one south-east Asian country by ensuring that foundation stock were not tick-infested and by subsequently applying appropriate quarantine measures.

Finally, the deleterious effects of *B. microplus* on cattle imported to areas favourable to this parasite may be reduced. First, if cattle have already been exposed to ticks in the country of origin they will have developed some acquired immunity, and will be less susceptible than those encountering *B. microplus* for the first time. There is thus a case for preferring cattle from areas enzootic for *B. microplus*, and also for subjecting cattle from other areas to controlled exposure to ticks before they are exported. Second, because the capacity to develop tick resistance is inherited and can be measured (Wharton, 1976), cattle could be selected for either individual or breed capability of resisting ticks. For example, Jersey cattle attain acquired resistance levels of nearly 98 percent against 85 percent for Holstein-Friesians (Utech, Wharton and Kerr, 1978), so that there is a good reason for recommending Jerseys ahead of Friesians in areas favourable for *B. microplus*. Third, it has recently been shown (Callow and Stewart, 1978) that active babesial infection coinciding with the first infestation of an animal with ticks interferes with the development of acquired immunity to ticks. This observation suggests that cattle experiencing tick, babesial and anaplasmal challenges immediately after arriving in a tropical environment should be effectively vaccinated beforehand to minimize parasitaemia at the initial challenge.

Turning to heartwater disease, although immunization against this condition can be performed, the procedures are relatively difficult to perform safely and conveniently (Uilenberg, 1977). Only limited advances in the study of heartwater have been made over the last twenty years, probably because of a relative lack of interest in the condition. There is a growing awareness of the significance of heartwater in attempts at livestock improvement in Africa (Illemobade and Leeflang, 1977), and an increased tempo of research can be expected. The difficulties of dealing with heartwater,

outlined by Uilenberg (1977) are, however, considerable, and no forecast of the rate of progress toward practical control can be made.

General recommendations

Those bodies primarily concerned with livestock improvement in developing countries — the lending institutions, bilateral and international aid agencies and the governments of the developing countries concerned — should continue to ask basic questions about programmes for cattle improvement. For example, why are they necessary, are there other priorities, and what is the cost-benefit relationship of establishing cattle industries in a particular country? Progress and achievements should be closely monitored and reviewed regularly.

Information, training and education. Influential and responsible bodies supporting and servicing the introduction of exotic cattle to difficult environments should become better informed of the complex problems associated with these enterprises. This applies mainly to the lending agencies and the relevant government departments in developing countries. Aid agencies might play a greater role than at present in providing information in the form of reports and manuals and in promoting active discussion and consultation between appropriate groups.

The lack of trained and committed people working in the animal industry in developing countries is relevant in the present context. The need is particularly great at two levels — field and laboratory investigation, and the management of cattle on farms. More postgraduate training, schools, workshops, training courses and practical experience on farms in developed countries than presently available would be of great benefit.

Research. More knowledge of the epidemiology of tick diseases, as a basis for rational control, is needed in all tropical environments. If the knowledge and experience to conduct the necessary investigations cannot be immediately provided by a country utilizing exotic cattle, the formation of international task forces trained to undertake this specialized work might be necessary.

Other worthwhile areas for more investigation are in the control of diseases caused by *Theileria*, the control of heartwater and in animal breeding. Progress made by groups in Israel, East Africa and recently in India opens up exciting possibilities for the control of theileriosis. If possible, extra financial support should be found for existing groups, and similar studies stimulated in other centres in the Near East and southern Asia. The impact of heartwater in Africa should be more closely examined, and, if the seriousness of this condition is confirmed, research into better means of control encouraged. Existing animal-breeding units, particularly in developing countries, should also receive more support in their work to improve productive potential and disease-resistance of indigenous and exotic cattle and their hybrids. Developed countries with tropical environments, such as Australia, could play a greater role in the development of cattle suitable for similar environments in developing countries. ■

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Progress in the selection of the Latin American Dairy Criollo

J. de Alba

The cattle that evolved in Latin America after the Spanish conquest are not really native cattle. Most countries in the Caribbean and in Central America derived their original stock from the Canary Islands via Hispaniola although some direct shipments were made to Argentina from Spain and to Brazil from Portugal. These movements occurred soon after 1492 and the rapid multiplication of herds in the newly discovered lands is truly a biological wonder (Rouse, 1977).

Several types of cattle evolved, largely through natural selection, but those inhabiting temperate climates have since been replaced by more productive types brought from northern Europe or North America. This is true for climates that are temperate due to latitude (Argentina, Uruguay, Chile) or altitude (the highlands of Colombia, Ecuador, Peru, Costa Rica and Mexico). In the lowland tropics, however, the introduction of non-Spanish, European types of cattle has been largely unsuccessful. Dairying in these areas has nevertheless developed, even in countries where there are no temperate highlands in which to breed cattle.

Cattle selected for milk production in several lowland areas developed along remarkably similar lines. A dairy criollo emerged in the area of Rio Limón, northwest of Maracaibo in Venezuela, on isolated farms in the lower Magdalena Valley of Colombia and in the province of Esmeraldas in Ecuador. In Central America the province of Rivas in Nicaragua became well-known for cattle of this type, which were used for on-farm cheese manufacture. Cuba, Puerto Rico and the Dominican Republic also had similar cattle. However, these cattle have disappeared almost completely from most countries in the Americas, since people assumed that further upgrading of criollos crossed with the more specialized dairy breeds would result in the same heterosis as that found in the first crosses. The same occurred in crossing criollos with zebu breeds.

Experimental herds designed primarily to preserve the dairy criollo and then to study more precisely the benefits of crossbreeding were begun in Turrialba, Costa Rica in 1950 with a grant from the Rockefeller Foundation (de Alba and Carrera, 1958), and in 1954 in Venezuela (Rios, Bodisco and Morillo, 1959). The knowledge gained from both projects has been put to good use in breeding programmes started in tropical Mexico, the Dominican Republic and recently in Ecuador, in cooperation with private producers. Several Latin American countries have taken advantage of accumulated selection improvements in the Turrialba herd.

Some of the salient findings in the selection of the dairy criollo and its crossbreds are briefly discussed in this article. The term "Tropical Dairy

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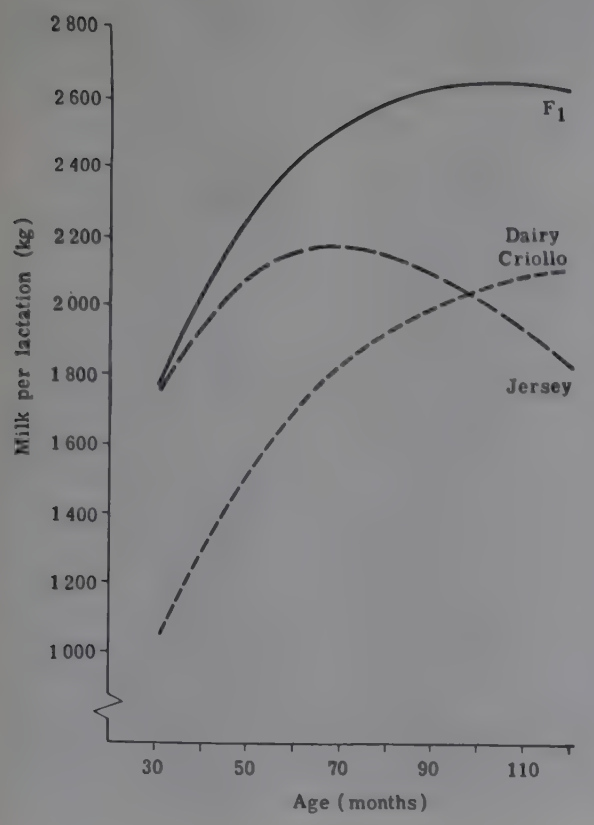

Figure 1 *Effect of age at time of calving on lactation yield for three different types of cows at Turrialba.* (Source: Meini, 1973.)

Criollo" is properly applied to these cattle, but the dairy criollo of Venezuela is sometimes called the Rio Limón Criollo, to distinguish it from other criollos having no dairy qualities. The dairy criollos of Turrialba are sometimes called Central American Criollos, but the term Reyna cattle is favoured in Nicaragua. It should be added that the experimental herd in Venezuela has a fraction of blood from the Reyna herd in Nicaragua.

Type description

The Tropical Dairy Criollo has a uniformly pigmented skin, very short hair and a lower number of hair follicles per skin area than European and zebu breeds. Coat colours vary from light dun to deep red with black markings on the extremities and around the eyes — more pronounced in bulls than in cows. A very distinctive feature is the light tail switch and the wrinkles of the skin around the eyes, or even between the horns in a few cases. The skin is thick and possesses abundant sweat glands. The configuration is angular, with a deep barrel and well-sprung ribs. One of the valuable qualities of the criollo is its ability to walk fast under scorching sun, which is associated with well-formed, wide, usually pigmented hoofs.

Well-balanced udders with well-placed teats are the rule, but some defective funnel-shaped udders or extremely wide teats are encountered. Occasional calves are born with too fine a bone structure.

Early experimental findings

In the early years officials at Turrialba and Maracay worked in close cooperation to establish uniform record keeping and methods of analysis; the results were published simultaneously in 1966 (Magofke, de Alba and Muñoz, 1966; Magofke and Bodisco, 1966). At Turrialba, in the original herd founded with cattle from Rivas, Nicaragua, Choluteca, Honduras and a few individual cows from Costa Rica, it was found that cows from Rivas were more productive, particularly those of a strain from the "Lopez Carazo Asylum for the Aged" in Rivas. Some of the highest yields recorded at Turrialba were from cows of that breeding, the highest standing unchallenged for 10 years at 3 600 kg for a 350-day lactation (the first 41 lactations recorded at Turrialba averaged 1 985 kg). The Lopez Carazo herd was disbanded in about 1950, after which no further cows of that strain were available. However, a large herd from Rivas, that of Don Joaquin Reyna, provided most of the bulls used at Turrialba. Most cows from Honduras were discarded, with only two or three leaving an imprint on current pedigrees. These cows had, however, proved their superior resistance to both ticks and tórsalos (*Dermatobia hominis*; Ulloa and de Alba, 1957).

The most important result of the establishment of these herds was their high fertility. For some years the herd at Turrialba maintained an enviable record of 1.4 services per conception. While this was not maintained in later years under artificial insemination, high fertility has continued to be one of the outstanding qualities of the breed. This has proved most valuable as low fertility has been one of the major deterrents to the progress of European dairy breeds in the tropics of Latin America (Carneiro, Brown and Pempeu, 1957; Garrido Rojo, 1976). Some of the first observations at Turrialba and Maracay are summarized in the table (Ríos and Bodisco, 1962; Carmona and Muñoz, 1966).

Other observations on valuable productive traits in the Tropical Dairy Criollo included a low early mortality of calves, the prenatal mortality being 1.1 percent in the Rio Limón Criollos,

Comparison of the fertility of criollos and other breeds at Maracay and Turrialba

Location and breeds	Number of observations	Services per conception	Number of observations	Calving interval (days)
Maracay				
Rio Limón Criollo	277	1.55±0.06	356	415± 3.7
Brown Swiss	86	2.19±0.24	100	465±38.2
Turrialba				
Central American Dairy Criollo	602	1.58	337	389
Jersey	272	1.55	129	387
Brown Swiss cross (majority with Red Sindhi)	329	1.63	123	417

Source: Ríos and Bodisco (1962); Carmona and Muñoz (1966).

as against 7.1 percent in Brown Swiss. They also showed a higher resistance to climatic stress than European dairy breeds (de Alba and Sampaio, 1957) with no slump in fertility during summer services; the time to conception was, for example, 120 days for Rio Limón Criollos in July-August as against 194 days for Brown Swiss (Bodisco and Mazzari, 1962).

Other advantages included higher solids in milk, both butterfat and protein, from the criollo breeds than from the more specialized dairy breeds. Butterfat averages were 4.60 percent in Maracay, and 5.08 percent in Turrialba. The high protein content of the criollo milk was also significant, ranging from 3.14 percent to 4.26 percent in Turrialba (Bateman and de Alba, 1961); neither Jerseys nor Sindhi-Jersey or Sindhi-Brown Swiss exceeded that average, nor did they reach the 4 percent content in their respective ranges.

Figure 2 *Cows from the Reyna herd which were sent as foundation stock to Turrialba.*

Disadvantages of the Tropical Dairy Criollo

The Tropical Dairy Criollo as found on private farms in Central America and Venezuela was being managed under somewhat primitive conditions, being milked once a day with the calf at foot and left to fend for itself through drought and feed shortages with little or no supplementary feed. Adaptation in such circumstances was likely to result in lower dairy temperament, or the sacrifice of milk yield to self-preservation. In fact, the population was found to have a high incidence of cows with difficult milk letdown (de Alba, 1960; Carnevali and Bodisco, 1966) and short lactations, with considerable interaction between the two measurements. Thus some of the early lactations at Maracay averaged 251 days and at Turrialba 271 days. Very heavy culling of cows with short lactations was practised early in both herds.

To be of any value, therefore, this meant that the populations selected both at Maracay and Turrialba had to show improved lactation performance and genetic superiority for milk production above the base level of the farms supplying the foundation stock. The task proved to be slow and difficult and the first assessments of genetic progress (Magofke, de Alba and Muñoz, 1966; Magofke and Bodisco, 1966) indicated that most progress would be made by the selection of dams of sires. Proven bulls, however, could not be used for extended periods in a small herd for fear of inbreeding depression (de Alba and Muñoz, 1964; Ríos and Bodisco, 1962). It was disturbing to find low repeatability within cow performance, which meant that non-genetic factors were influencing cow performance. Several conclusions were drawn; it was felt that more time was necessary to assess the genetic value of the selected experiment-station herds subjected to twice-daily milking and milked without the calf; that a policy of rapid turnover of young bulls selected from outstanding cows should be instituted; and, most of all, that a larger population was necessary to promote genetic improvement.

Working to a new time-scale

These conclusions were acted upon more successfully in Venezuela than at Turrialba, with a herd-testing scheme quickly started in the area of Rio Limón, Venezuela (Bodisco *et al.*, 1962). The move from Maracay to Rio Limón disrupted the continuity of some of the selection effort. Given the better physical facilities at Rio Limón, the availability of more land and the advantages of being in the midst of the producers of the breed, success seemed more likely; but many of the lifetime averages were affected and time was lost in re-establishing a sound management system at the new station.

Attention was centred on the study of crossbreeding in addition to the selection of the pure Central American Criollo herd. The crossbreeding activity was encouraged by pressure from producers who wanted a cow with a higher production rate, but with the tropical adaptability of the criollo. During this period uncoordinated attempts at crossbreeding were taking place in many lowland areas of the Latin American tropics. Of these, the best-organized group was in Carora, Venezuela, where a breed of cattle that included Brown Swiss and Venezuelan Criollo was favoured (Bodisco and Ríos, 1962). The Carora type is now a highly productive and well-

Figure 3 *Dairy criollo cow from the Dominican Republic. This is the type being acquired at Santiago de los Caballeros.*

adapted breed. At the time (1955), before the widespread use of frozen semen, and with Costa Rica having no Brown Swiss population of any consequence, the crossbreeding project at Turrialba was designed to study the F_1 Jersey × Central American Dairy Criollo, using reciprocal crosses within a time span of no less than 15 years, so that a number of bulls and lifetime averages could be included. This period would also allow for the building of a more homogenous base for selecting a Central American Dairy Criollo. Some encouraging results have begun to appear which could lay the foundation for programmes in other countries.

New findings

The cooperative work in the Rio Limón area has been maintained with success though with no uniform intensity, and has included at various times some 14 establishments. The length of lactation is no longer a problem, with averages of 298 days, based on 836 observations, reported recently (Perozo, 1977). Average production in these lactations, without any concentrate feeding reached 1 867 kg, whereas figures published in 1962 (Bodisco *et al.*, 1962) gave an average of 1 719 kg.

Accumulated data will now allow more precise genetic analysis and the project is ready to test bulls coming from outstanding cows. The longevity of the dairy criollo has been fully documented by more recent data, which indicate no reduction in milk production up to the twelfth calving for the Venezuelan cow.

The latter finding means that the age correction factors necessary to take advantage of information on all lactations need to be specific for the dairy criollo; this was done by Meini (1973) for the Turrialba herd. The surprising finding was that correction factors are constant at 1.00 for adult production in lactations initiated from the 97th month of age to the 120th month of age, whereas Jerseys in the same environment age much faster.

The data on crossbreds at Turrialba indicate that the F_1 Jersey × Central American Criollo cow possesses a unique hybrid vigour which manifests itself in the full early production typical of the Jersey, but with the longevity of the Criollo, all this is realized at a higher level of production than with either parent breed. Figure 1 illustrates this remarkable and economically important finding.

Extension of work into Mexico and the Dominican Republic

A nucleus of purebred Central American Criollos was brought to Mexico from Rivas, Nicaragua, in 1964, with two bulls donated by the Turrialba herd to the Mexican Association of Animal Production. This herd was slow in producing experimental results owing to changes in location; it finally settled near Tampico, on the Gulf Coast of Mexico in 1973.

Lactation yields obtained from individual cows of known age were beginning to emerge in 1975. Some respectable averages have been achieved under conditions of once-a-day milkink, with no supplements, in a climate with a pronounced dry season: 1 274 kg in 1975 and 1 328 kg in 1976 for age-corrected lactations, using the factors suggested by Meini (1973) for the Turrialba herd.

Young bulls from outstanding cows are beginning to appear and they will be used in a region where milk recording is being initiated south of Tampico. Frozen semen from Turrialba

has been in use in Mexico since [illegible] and breeding values on the young bulls will be completed using, in part, the Turrialba data. Frozen semen will be available from the Mexican herd in 1978. It is expected that two to four young bulls will become available every year. Frozen semen will be stored and sold to public and private establishments within Mexico and elsewhere. The bulls will be sold to private breeders under the condition that, should progeny tests be successful or semen be required from the bulls again, they will be brought back to the station for short periods. Well-organized progeny testing will necessarily be slow until herd recording is extended successfully to a larger population. This is being attempted now on the Gulf Coast of Mexico. The main effort will be directed toward crossbreeding with Brown Swiss and Holstein cattle on private farms, although criss-crossing with Jerseys and Canadian Holsteins is also under study at the station.

In the Dominican Republic an effort is underway to build up a selected criollo herd based on good cows still found in the hands of smallholders all over the island. These will also use frozen semen from selected bulls from Turrialba. The scheme calls for a cooperative farmer project for milk recording and supervised crossbreeding. This will initially be based on the success of the F_1 population at Turrialba, but will continue into criss-crossing, alternating the selected dairy criollo bulls with semen from proven Holstein and Brown Swiss bulls from the USA and Canada.

Goals for the immediate future

The full benefit of the herd recording at Rio Limón, Venezuela has not been realized because a well-organized artificial insemination programme has not yet been implemented. Data, experience and bulls are available; a large-scale human organization is the missing ingredient. The Turrialba herd is at some disadvantage because it is situated in a sugar cane and coffee producing area, and cooperators are scattered geographically; but this does not mean that no progress has been made. Recent shipments of semen to Bolivia and the Dominican Republic are the best evidence of this.

In Mexico, as in most countries of the Latin American region, the low level of organization of producers is an obstacle, and the establishment of a milk-recording scheme south of Tampico is an effort to encourage a few producers to form a recording organization of their own.

Oddly enough, the last project to start, the one in Santiago de los Caballeros, Dominican Republic, has the best chance of success. It has some excellent cows in the hands of a private foundation and has an immediate area of influence that includes producers already organized into a cheese cooperative.

If similar groups could be organized in other lowland areas of the tropics, the full benefit of crossbreeding based on long years of selection both at Rio Limón and Turrialba would result in an urgently needed improvement in milk production in tropical Latin America. ■

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Use of agro-industrial by-products in feeding ruminants in India

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The national livestock herds in India are the largest in the world, but owing to indiscriminate breeding and inadequate nutrition their production levels are low. Comparison of the feed required to maintain the country's 227 million cattle, 44 million sheep, 89 million goats, 6 million pigs and 117 million poultry on an adequate level of nutrition (Ranjhan, 1973), with the total estimated feed available (Ministry of Agriculture, 1972), suggests that there is an 80 percent shortfall in concentrates and a 40 percent shortfall in roughages. These together account for a deficiency of about 65 percent in digestible crude protein (DCP) and 60 percent in total digestible nutrients (TDN). Recent government estimates (National Commission on Agriculture, 1976) suggest a national shortage of about 44 percent in concentrates, 44 percent in dry fodders and 38 percent in green fodders.

Various efforts are being made to increase national fodder production, but there is no doubt that, for many years to come, crop residues and by-products will constitute the principal components of the diet of ruminant animals in India. Research and development work has therefore been channeled toward the more effective utilization of these so-called "new feed resources" through the development of appropriate processing technology to help improve their nutritive value. These developments have taken place in institutes such as the National Dairy Research Institute (NDRI) and the Indian Veterinary Research Institute (IVRI). The Indian Council of Agricultural Research has also initiated a national coordinated research project entitled "Investigations on agro-industrial by-products and industrial waste materials for evolving economic rations for livestock". This has been in operation since 1967 at eight centres in the country and has a project coordinator located at IVRI, Izatnagar. The centres are all engaged in studying ways and means of incorporating different agro-industrial by-products and wastes into livestock rations in various combinations. Where the by-products contain toxic substances, these are identified, and processes are developed to detoxify them. As a result, most of the by-products have found their way into the feed-compounding industry, which has been growing at a very rapid rate. Some of the by-products are also fed directly to livestock on smallholdings.

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Crop residues

About 220 million metric tons of straws and stovers are produced annually in India. Approximately half the gross energy present in the organic matter of India's rice and wheat crops is to be found in the straws. Rice and wheat straw are used by farmers throughout the country as the major roughages for livestock feeding. This is due not only to their abundant availability but also to the lack of cultivated green fodders for animal feeding.

The stovers of oil-bearing crops like groundnut (*Arachis hypogea*) and rape (*Brassica* sp.) have also been successfully used at IVRI in various feeding trials; farmers are now incorporating them in increasing quantities in feeding schedules for animals.

The straws are of poor nutritive value and their voluntary intake by animals is limited by their low nitrogen and high lignin contents and their dustiness. Rice straw is rich in soluble potassium and in soluble calcium oxalates. Animals fed on rice straw show a negative calcium balance, because the utilization of calcium is adversely affected by the formation of bicarbonates, resulting in an alkaline pH which affects calcium absorption in the alimentary tract. Various physical and chemical treatments of rice straws are used in India to improve their nutritive value and intake. On small farms, the most commonly used physical treatment of the straw is to soak it in water before feeding it to the animals. This practice is commonly used by farmers in the north-

ern part of the country. The [illegible] removes soluble oxalate from rice straw. Chaturvedi Singh and Ranjhan (1973) found that the pre-soaking of wheat straw for 1-2 hours in 1 litre of water per kg of straw significantly increased voluntary consumption of the straw in zebu and buffalo calves compared with unsoaked straw. The digestibilities of crude protein and crude fibre were depressed, but the digestibility of the nitrogen-free extract increased significantly on soaking. The availability of digestible energy and metabolizable energy and the production rates of total volatile fatty acids were higher in zebu and buffalo calves fed water-soaked straw. These results suggest that the pre-soaking of straw for 1-2 hours in water is generally good for the animals consuming it.

The chemical treatments used in India for improving the nutritive value of straw are alkali, and impregnation with urea and molasses.

Alkali treatment of straw. In this process, sodium hydroxide is used as the delignifying agent (Sen, Ray and Talapatra, 1942). The roughage used to be soaked in large vats of sodium hydroxide solution and then washed to remove the residual alkali. However, treatment by this method had several drawbacks: there was a heavy loss of nutrients (20-25 percent) by leaching during washing; the cost of the finished product was high; and it was not competitive with other feedstuffs. For these reasons, the process was modified to a spray treatment of the straw with a limited quantity of alkali and without any further washing (Wilson and Pigden, 1964; Singh and Jackson, 1971). The optimum concentration of alkali for this treatment was found to be 3.3 percent. There was a marked increase in nutritive value in terms of digestible organic matter intake for both ground and chaffed wheat straw that had been spray treated with 3.3 percent NaOH (Singh and Jackson, 1971). Over a period of six months' continuous feeding, no adverse effects were observed even at higher levels of alkali treatment, *viz.* up to 10 percent. The nitrogen, calcium and phosphorus balances were not adversely affected using 3.3 percent of alkali.[1]

Impregnation of straw with urea and molasses. The addition of urea to straw increases its nitrogen content and thus exerts a favourable influence on rumen microbial fermentation. The addition of molasses provides soluble carbohydrates for effective urea utilization. A combination of 1.5-2.0 percent urea, 10 percent molasses and 0.5 percent mineral mixture has been shown to improve the digestibility of organic nutrients and increase the voluntary feed intake of cattle and buffaloes (Gupta *et al.*, 1968).

On the basis of these results, the impregnation of straw with urea and molasses was undertaken on a large scale during the 1972-73 droughts in Maharashtra state as well as in the cyclone-hit areas of Tamil Nadu in 1977, when large numbers of cattle and buffaloes were saved from starvation and death.

Rice husks

About 10 million metric tons of rice husks and 2 million metric tons of rice bran are potentially available as by-products of the rice milling industry in India. Rice bran is used in rations for livestock and poultry to the extent of 40 and 20 percent respectively, together with cereal grains and protein supplements. About 55 percent of the rice husks available is in the form of "huller bran", and this is fed to the animals. The remainder poses problems for disposal and/or proper use; at present, about 30 percent is used as fuel in boilers.

Rice husk contains 2.9-3.6 percent crude protein, 0.8-1.2 percent ether extract, 39-42 percent crude fibre and 15-22 percent ash. Its use as a livestock feed is limited because of its high silica content (14.5-17.5 percent). However, attempts have been made at IVRI to process the rice husk and make it suitable for feeding to livestock by treating it with alkali and steam pressure. The rice husks can then be incorporated to the extent of 10 percent in rations for ruminant animals.

Sugar cane by-products

India is one of the major sugar cane growing countries. The by-products of the sugar industry — molasses, bagasse and sugar cane tops — are therefore available in substantial quantities.

Molasses. The total production of molasses in the country is about 2 million metric tons. As a rich source of soluble carbohydrates, approximately 70 percent of the molasses is devoted to alcohol production. About 3-5 percent is used in tobacco curing. Where it is incorporated in livestock rations, it seldom exceeds 5-10 percent of the total.

Recently, research efforts have led to the formulation of a liquid diet based on a urea-molasses mixture that is designed to supply the major portion of the energy and nitrogen required by different classes of ruminants. The use of this urea-molasses liquid feed together with small amounts of cereals, fodder and protein supplements for crossbred calves resulted in a growth rate of 500-650 g per day (Pathak, 1973); the liquid diet provided about 60 percent of the energy consumed by the animals. The same diet has also been found to be useful for lactating crossbred cows producing 8-10 litres of milk per day. There was no difference in milk yield between cows given the urea-molasses liquid feed together with small amounts of cereals, fodder and protein supplements, and cows receiving conventional concentrate and roughage-based rations (Krishna Mohan *et al.*, 1976; Pathak *et al.*, 1976 and Ranjhan, Krishna Mohan and Pathak, 1976).

Bagasse. The fibre content of Indian sugar cane is 15-17 percent. About 5.26 million metric tons of bagasse is produced annually in the country, but it is used primarily as a fuel for boilers in sugar mills. It is

[1] A comprehensive assessment of the alkali treatment of straw is given in M.G. Jackson's article, *Treating straw for animal feeding — an assessment of its technical and economic feasibility*, published in this issue of *World Animal Review*. The Editor.

Bagasse bales intended for feeding livestock.

a rich source of carbohydrate but is low in protein (2.3 percent) and high in lignin (20 percent). It has been used successfully as a roughage for ruminants. Murthy and Sarma (1969) found that a ration consisting of 20 kg bagasse, 6 kg molasses, 0.8 kg groundnut cake, 0.34 kg common salt and 0.34 kg mineral mixture could provide the maintenance requirements of adult animals. It has also been found possible to replace the protein in groundnut cake by urea nitrogen in such a ration. Large scale use was made of this ration in cattle camps established during the severe drought of 1973 in the state of Maharashtra, when more than 34 000 animals were fed on it (Ranjhan, Jayal and Sawhney, 1974).

Sugar cane tops. These are available in abundance from November to April during the cane-crushing season and often serve as the principal roughage for cattle and buffaloes. Farmers normally supplement the tops with small quantities of oilcake. In trials at IVRI, the tops have been included in the rations of ruminant animals either *per se*, or after conversion into silage. When supplemented with 500 g of groundnut cake and 40 g mineral mixture, they can provide the maintenance requirements of animals weighing 350 kg.

Forest by-products

Since approximately 20 percent of the land area in India is under forest, a substantial quantity of forest by-products in the form of leaves and seeds is available for livestock feeding. Studies conducted at IVRI on the nutritional value of some 40 species of tree fodder suggest that some of them are highly nutritious to cattle, while most of the others may be fed in small quantities in combination with conventional feeds. The DCP values of the leaves of some fodder trees and shrubs like gaug (*Millettia aurinculata*), siras (*Albezzia lebbak*), sanjana (*Moringa pterygoserme*), bel

Preparation of liquid urea/molasses mixture for impregnation into straw.

(*Aegle marmelos*), tut (*Morus indica*) and bhimal (*Grewia oppositifolia*) compare favourably with those of cereal brans and some of the leguminous fodders; but the energy values are comparable only with those of grass and hay.

Large quantities of oak kernel (acorns) are available from the oak forests. However, these cannot be used in appreciable amounts in cattle and poultry rations because of the high content of tannin and other undesirable qualities (Katiyar, Ravi Prakash and Ranjhan, 1973).

Oil seeds from trees

About 6.7 million metric tons of oil seeds are produced by trees in India, but owing to the lack of organized collection facilities, only 4-5 percent of this potential total is collected and utilized. However, this is being overcome rapidly because of the growing demand for oil seeds in the soap and confectionery industries. The types of oil seed that are more important for livestock feeding are discussed below.

Salseed (Shorea robusta). About 5 000 km^2 in the sub-Himalayan forest zone is devoted to sal, with a potential production of some 55 million metric tons of sal kernel and 6 million metric tons of fat. The sal kernels are usually available during the months of May and June before the onset of the monsoon rains. After extraction of sal oil by the confectionery industry, large quantities of de-oiled salseed meal are available for livestock feeding. The conflicting reports received on salseed meal prompted the Indian Council of Agricultural Research to organize, in 1970-71, a coordinated research programme at eight nutritional centres in the country (IVRI, NDRI, Kerala, Madras, Pantnagar, Anand, Bangalore and Bhubaneswar) to determine its nutritive value. The results showed that de-oiled salseed meal may be used as an energy source (with no DCP, but with 45 percent TDN) up to a 20 percent level in concentrate mixtures for cattle, without any detrimental effects on production. De-oiled salseed meal is now routinely used in the feed compounding industry.

Feeding of bagasse impregnated with 1% urea and 10% molasses in cattle camps in Maharashtra.

Salseed meal contains about 8-10 percent tannin; this may slow the breakdown of dietary protein into NH_3 in the rumen. But the presence of too much tannin would interfere with the overall utilization of energy and protein by lowering the digestibility. Salseed meal should therefore not be used at more than the recommended levels, which are 20 and 10 percent respectively of the untreated meal for growing and lactating animals. In the case of poultry, the recommended ration levels are 5 percent for layers and 8 percent for growers. Attempts to improve the nutritive value of salseed meal by removing tannins with various chemicals (e.g., sodium or calcium hydroxide) have not been successful. Despite this, during 1975-76, about 80 000 metric tons of de-oiled salseed meal were used by the organized sector of the livestock industry in India.

Neem seed (Azadirachta indica). The use of neem oil in the soap industry results in an annual production of about 75 000 metric tons of de-oiled neem seed cake as a by-product (Ketkar, 1976). To explore the possibility of using neem seed cake as a livestock feed, the Khadi and Village Industries Commission, Bombay, supplied the cake to 12 research centres in the country. The crude protein content of the cake varied from 11 to 25 percent. The cake had a bitter taste due to the presence of nimbidin and could only be fed to animals as a small component of an otherwise palatable concentrate mixture. The DCP and TDN contents for calves were 8.4-8.9 and 57.8-60.8 percent respectively (Bedi, Vijjan and Ranjhan, 1975). Untreated neem seed cake when incorporated at a 10 percent level in the concentrate mixture depressed the growth rate. Workers at IVRI observed that alkali-treated neem seed cake was palatable to crossbred calves when it was included at the 50 percent level, but the growth response was inferior to the control ration (Nath and Vijjan, 1975). Further work on processing is in progress.

Mahua seed (Madhuca indica). Mahua cake contains saponins (mowrine) which are not palatable. As

early as 1947-48, IVRI worl[illegible] ported that mahua cake could be incorporated at a 10-25 percent level in concentrate mixtures for cattle if it is steeped in water for two hours before feeding. More recently, they have developed a process by which mahua cake could constitute 50 percent of the concentrate mixture for crossbred calves; it can also replace all of the protein from groundnut cake in concentrate mixtures for growing calves. These results suggest that there is a vast potential for the utilization of this plant protein in animal feeding. The DCP and TDN contents of processed mahua cake are 8.6 and 45.6 percent respectively.

Rubber seed (Hevea brasiliensis). The potential availability of rubber seed cake for animal feeding in the state of Kerala is about 150 000 metric tons. Its DCP and TDN contents for cattle are 18.6 and 54 percent respectively. It can be economically used up to a 20 percent level in concentrate mixtures for calves and milch cows without adverse effects on growth rate or milk yields.

Tobacco seed (Nicotiana tabaccum). The potential production of tobacco oilcake in India is about 17 000 metric tons per annum, but due to a lack of incentives for seed collection, only about 4 500 metric tons are utilized. The cake contains 26.3 percent crude protein and can be fed as a concentrate to bullocks; it can also be incorporated in concentrate mixtures for dairy cows up to about 25 percent of the ration.

Dhupa seed (Vateria indica). The availability of dhupa cake in India is estimated to be about 20 000 metric tons per year. The cake contains 2.2 percent DCP and 45.8 percent TND and can be used up to about 20 percent in concentrate mixtures for ruminants.

Fruit and vegetable factory by-products

The total quantity of fruit and vegetable products manufactured in India in 1970 was of the order of 156 000 metric tons. The waste materials from this manufacturing industry were estimated to amount to some 25 000 tons, the principal contributors being mango, citrus, pineapple, green peas and tomatoes (Kerala Veterinary College, 1975). The main problem arising in the utilization of waste materials from fruit preservation factories is their high water content. Suitable technology needs to be developed to remove the excess water without at the same time removing appreciable quantities of nutrients.

In India, tomato pomace is available during February and March; sun-drying is therefore feasible and economical at this time of the year. Sun-dried tomato pomace is ground and used as an ingredient in concentrate mixtures, comprising up to 33 percent of the mixture. It contains 14.3 percent DCP and 41 percent TDN.

Citrus peels are also available during February-March and can be dried in the sun. Dried and ground citrus peels and pulp can also constitute up to 33 percent of the concentrate mixture and can replace wheat bran.

Mango seed kernels contain 6 percent DCP and 70 percent TDN. Early work suggested that this rich source of energy could be utilized at a 20 percent level in production rations for cattle (Kehar and Chandra, 1945). More recent experiments at Anand have demonstrated that it can be used satisfactorily in concentrate feeds at levels of up to 40 percent and 10 percent respectively for working bullocks and milch cows. With the development of a mango dehuller at Pantnagar and the extraction of oil on a large scale from mango kernels, the resulting cake is being used increasingly with other ingredients in concentrate mixture for livestock.

Marine wastes and by-products

Seaweeds of different varieties totalling some 80 000 metric tons of dry materials are available annually in India. Agar-agar and sodium alginate are extracted from the *Sargassum* species of seaweeds. The resulting by-product is rich in minerals, especially calcium (4 percent), and is suitable for livestock feeding. Some seaweeds are rich in protein. Depending on the source therefore, marine wastes and by-products can be used to replace part of the protein in livestock feeds or as an added source of minerals.

A large amount of prawn and shrimp waste is also available in India as a processing by-product. Such waste contains about 40 percent crude protein, but the moisture content is high (77 percent); this creates problems of collection, preservation and transport. A process has recently been developed for the manufacture of prawn-waste meal, which should lead to its increasing availability as a livestock feed.

Animal wastes

India has about a third of the world's animal population, but animal wastes are seldom utilized as livestock feed. About 33 percent of all cattle wastes in the country are used for manurial purposes; the rest is used as fuel. Ichhponani and Lodhi (1976) have estimated that the energy that could be derived from animal wastes in India is equivalent to that from 4.3 million metric tons of cereals; the crude protein equivalent would amount to 4.2 million metric tons of oil seed cake. However, little work has been done on the possible utilization of these materials for livestock feeding.

Miscellaneous by-products

Tapioca (Manihot utilissima) by-products. Extensive studies have been undertaken on the use of tapioca leaves and tapioca waste for animal feeding. Tapioca leaf meal prepared after sun-drying and processing is a good source of protein, rich in essential amino acids like leucine, valine, isoleucine and lysine. It contains 15.3 percent DCP and 45 percent TDN and can be profitably included at a 30 percent level in concentrate mixtures for cattle, without any adverse effects. The hydrocyanic acid present in the leaf meal (17.5 mg HCN/100 g) is apparently harmless at this level of incorporation.

Tapioca waste is a by-product of the starch industry. Experiments with calves and lactating cows have shown that it contains 2 percent DCP and 64 percent TDN and can be used to advantage as an energy ingredient in substitution for maize.

Tea (Camellia sinensis) waste. This material is the residue after the extraction of instant tea concentrate from tea leaves. It contains 80 percent moisture. The sun-dried material contains 8.3 percent DCP and 45 percent TDN and when incorporated in the rations of growing calves at a 20 percent level, it gives a satisfactory growth rate.

Coffee (Coffea arabica) husk. In 1970, India produced 63 500 metric tons of coffee, which yielded 44 450 metric tons of coffee husk. Coffee husk contains 3 percent DCP and 50 percent TDN and can be economically incorporated at a 10 percent level in concentrate mixtures for calves as a substitute for rice bran.

Guar (Cymopsis psoraloides) meal. This meal is a by-product of the guar gum industry and is rich in protein (43-46 percent). Sadagopan and Talapatra (1967) reported a growth rate of 503 g per day in calves fed a concentrate mixture containing 20 percent guar meal and 80 percent wheat bran, fortified with 1 percent chalk and common salt; the roughage component of the feed was wheat straw and berseem. Guar meal is now used extensively in India as a protein supplement for cattle. It is incorporated up to about 10 percent in poultry feeds.

Silk worm pupae meal. This is a by-product of the sericulture industry. After the silk is removed from the cocoons, the pupae are crushed and the oil is extracted. The residual product is a good source of animal protein for poultry feeding, and is now used widely in India. It contains 65.5 percent crude protein and 6.2 percent ether extract, 91 percent organic matter, 0.4 percent calcium, and 0.9 percent phosphorus on a dry matter basis (Zubairy and Khan, 1969). Silk worm pupae, when fed with molasses and wheat straw, is also a suitable feed for sheep.

Conclusions

The livestock industry of India will continue to be dependent for many years on crop residues and by-products. Many of the latter have been nutritionally evaluated, and appropriate treatment methods have been developed, where necessary, to increase their feeding value. The rapidly expanding feed-compounding industry now incorporates many such by-products in commercial feeds, but their effective utilization at the small farm level still lags behind. Further pilot studies at the farm level combined with efficient extension programmes are therefore warranted. ■

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Treating straw for animal feeding – an assessment of its technical and economic feasibility

M.G. Jackson

In November 1976 the Food and Agriculture Organization of the United Nations (FAO) organized a technical consultation on new feed resources (FAO, 1976). One session of this consultation was devoted to the improved utilization of poor quality roughages. It was noted that a number of methods of treating straws to improve their feeding value have been developed and that the widespread application of these methods could substantially increase effective feed resources. It was, however, clear that none of these techniques could be unreservedly recommended for implementation in developing countries at the present time. As a follow-up action, therefore, FAO arranged for the services of a consultant, the present writer, to make an assessment of the feasibility of straw treatment from both a technical and economic viewpoint. The consultant undertook this assignment during November and December 1977 and January 1978, visiting institutions engaged in straw utilization research in India, Malaysia, Egypt, United Kingdom, Denmark, Norway, the Netherlands and France. He also corresponded with scientists in some countries that it was not possible for him to visit. A full report of this consultancy has been published by FAO (FAO, 1978). The present article is a summary of that report.

The object of straw treatment is to increase digestibility and/or voluntary consumption, thus increasing the intake of digestible energy. A variety of methods of straw treatment now exist that meet this objective. The simple enrichment of straws with minerals and protein or nitrogen supplements is not considered treatment, though these supplements do enhance the efficiency of straw utilization by ruminants; such supplementation is a valuable complement, or indeed even an indispensable complement to straw treatment as will be pointed out later. Treatment methods may be classified as physical, biological and chemical.

Physical methods of treatment

The main physical methods of treatment are grinding and pressure cooking. Grinding increases the voluntary consumption of straw leading to digestible-energy intakes of up to 30 percent. In terms of net-energy intake the increase is somewhat more than this because the net-energy value of straw is increased by grinding. Even then, grinding is only about half as effective as alkali treatment. There is a small additive effect of grinding and alkali treatment, but there is insufficient data at present to evaluate this effect nutritionally or economically.

The pressure cooking of straws can increase digestibility, but its usefulness cannot be judged at present as there is insufficient information. If this method proves to be as effective as the best alkali treatment methods it merits further study.

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Biological methods of treatment

The biological treatment of straw is based on the use of fungi that degrade lignin. Organisms that degrade cellulose and hemicellulose are of no use since they only deplete the straw of nutrients that the ruminant itself can digest. While there are apparently no organisms that degrade only lignin, there are some, notably the white-rot fungi, that degrade more lignin than they do cellulose, thus leaving a residue with a lower percentage of lignin than the original material. Large increases in digestibility *in vitro* have been measured in laboratory experiments. Farm-scale treatment methods have to be devised and feeding trials with animals conducted to evaluate the usefulness of this method of straw treatment.

Chemical methods of treatment

A variety of methods of treating straw with alkalis — NaOH, NH_3 and $Ca(OH)_2$ — have been developed. They vary in cost of treatment, effectiveness and suitability for differing situations. They are broadly classified into soaking methods and spray methods. In the former the straw is soaked in 10 or more litres of a 1.5 percent NaOH solution per kg straw and washed in a closed system from which water is not discarded. A wet straw is produced with a sodium content of about 2 percent. Organic-matter digestibility increases by at least 20 percentage units for an expenditure of 4 kg of NaOH/100 kg straw. Spray methods increase digestibility by 15 units with 4-5 kg NaOH if heat is ap-

plied; otherwise the increase is only about 10 units. When spray-treated straw is the main component of the diet, the level of NaOH/100 kg straw must be limited to 4-5 kg to avoid stress to animals from sodium. Higher levels of up to 7-9 kg/100 kg straw can, however, be used to obtain still greater increases in digestibility (16-20 units) when straw constitutes only half the diet. $Ca(OH)_2$ is as effective as NaOH, but, because it is less soluble, reacts more slowly; $Ca(OH)_2$-treated straw must therefore be ensiled for about 5 months. NH_3 is less effective than NaOH, the maximum increase in digestibility being about 12 units. This is achieved with 3-4 kg NH_3/100 kg straw at ambient temperatures and treatment periods of 2-3 weeks. Heating does not appear to improve the efficiency of NH_3 treatment. Brief descriptions of the important methods so far developed are given below.

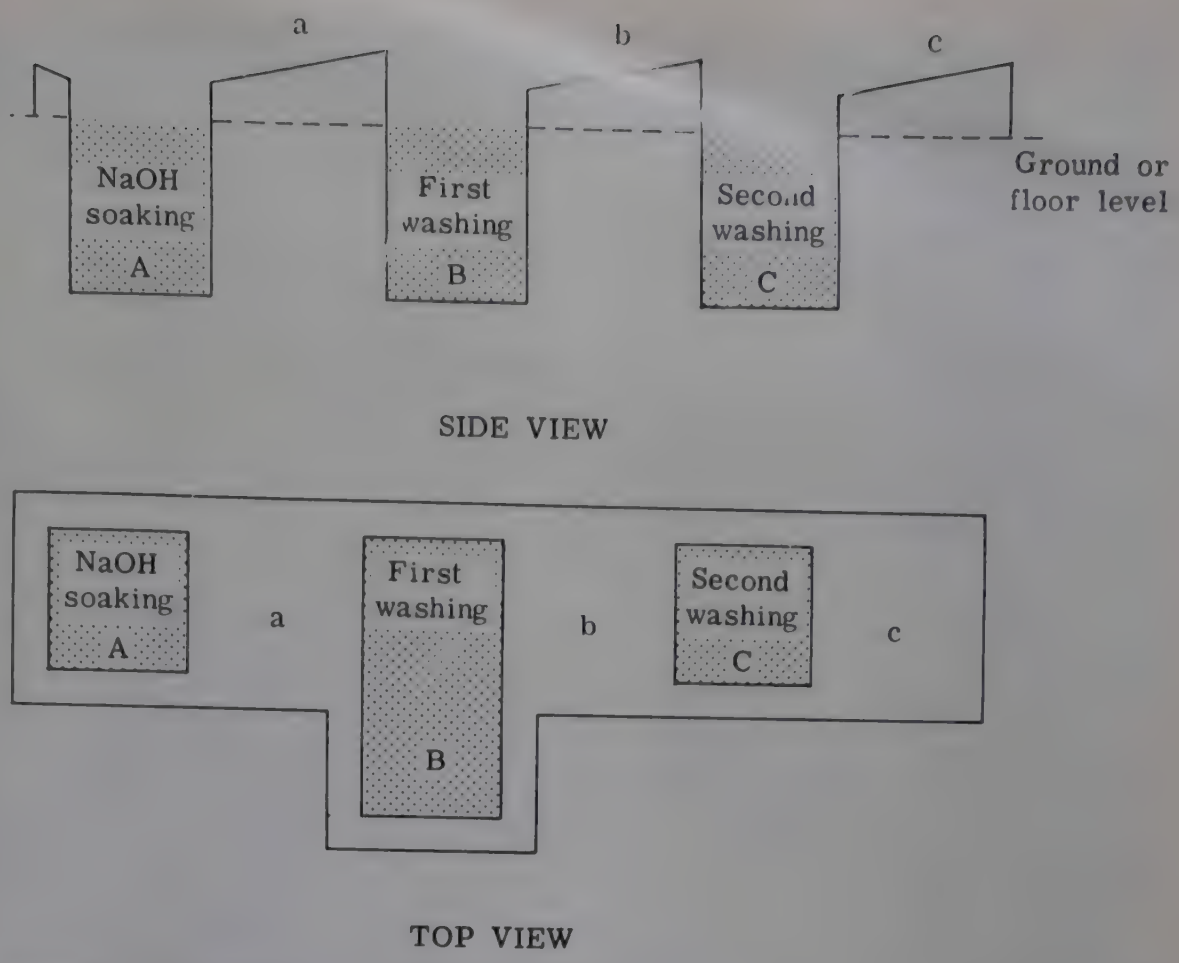

Figure 1 *Arrangement of treatment tanks for the treatment of straw by the modified Beckmann (Torgrimsby) method.*

Modified Beckmann (Torgrimsby) method

The Beckmann method of treatment involves soaking straw for 24 hours in a tank containing a 1.5 percent sodium hydroxide solution and then washing in a continuous flow of water for another 24 hours. This is still the most effective method of treatment, increasing organic-matter digestibility by about 25 percentage units, but it has several serious drawbacks. It is expensive because about 8 kg NaOH are used per 100 kg straw and 20-25 percent of the original straw dry matter is leached out. A large volume of fresh water is needed — up to 50 l/kg straw. Finally, this method causes river pollution. Owing to these disadvantages, the Beckmann method never became a commercial reality except in Norway and even there straw treatment by this method has had to be given up in recent years because of anti-pollution laws. All the other alkali-treatment methods have been devised in an endeavour to overcome the defects of the Beckmann method.

In the Torgrimsby method no wash-water is discharged from the system and leaching losses are nil. Only 4 kg NaOH are used to treat 100 kg straw. The easiest way to visualise the operation of this process is to consider how it would work on a small, unmechanized scale. Three tanks are needed, each with an attached draining board (Figure 1). Tank A contains 1 000 l of a 1.5 percent NaOH solution in which 100 kg straw, in bundles or bales, are soaked. The first washing tank (B) contains 2 000 litres of water and the second washing tank (C) contains 1 000 litres. Tank B is twice as long as tanks A and C (see "top view" of Figure 1). To the right of each tank in the diagram is a sloped draining board (a, b and c). The straw can be lifted in and out of the tanks manually or with a hand-operated block-and-tackle on an overhead rail. The daily sequence of operations is as follows:

Time	Operation
07.00	Remove treated straw from *A* and place on *a* to drain (the straw was placed in *A* the day before at 12.00 noon).
08.00	Remove drained, treated straw from *a* and place in *B*. Place fresh (dry) straw (100 kg) in *B* as well.
12.00	Make up NaOH concentration of *A* by adding 4 kg NaOH. Remove fresh straw from *B* and place in *A*. Remove treated straw from *B* and place on *b* to drain.
13.00	Remove treated straw from *b* and place in *C*.
16.00	Remove treated straw from *C* and place on *c* to drain.
17.00	Transfer 300 litres of water from *C* to *B* to make up the volume of the latter (the 100 kg fresh straw removed 300 l water earlier).
18.00	Wash treated straw on draining board *c* with 300 litres fresh water by pouring it over the straw. (This runs into *C*, thus making up its volume.) After this final washing, treated straw is ready for feeding.

The treated straw has a dry-matter content of about 20 percent and a sodium content of 2 percent. Dry-matter digestibility *in vitro* has been found to increase by 32 units, considerably more than for any other method when 4 kg of NaOH are used. Digestibility *in vivo* is being determined, but increases of 20 units or more are anticipated on the basis of *in vitro* results.

The Torgrimsby process appears to be ideal for small-scale farm use in Asia. It can be mechanized, however, and can thus be scaled up to meet the needs of farms in Europe.

Figure 2 *Daily spray treatment of straw. This is the easiest method, but is less effective than other methods of NaOH treatment.*

It could replace the traditional Beckmann process in Norway and thus allow existing cooperative and farm treatment plants to operate again without infringing anti-pollution laws.

Daily spray treatment

Dry straw is sprinkled or sprayed with a dilute NaOH solution so that it is uniformly wetted. A batch is prepared every day. It is desirable to use the straw as feed the day after it is treated as digestibility increases significantly with time over the first 24 hours after treatment. The operation may be done by hand where only a few animals are to be fed, using a sprinkling can and a fork to turn the straw while it is being sprinkled (Figure 2). For complete and uniform wetting, experience suggests 200 litres of solution per 100 kg straw. If a pressure sprayer is used this can be reduced to 100 litres. For treating larger batches of straw, a horizontal feed mixer or a "mixer-trailer" designed to mix silage and concentrates can be fitted with a pump and spray boom. In this case uniform wetting can be achieved with 50 litres of solution. Other equipment might be devised. For example, a screw auger with spray nozzles inside it would give a continuous flow of treated straw.

Straw treated by this method is moist, has a pleasing yellow colour and a smell of caustic soda. Animals eat it readily and when fed *ad libitum* usually eat 10 to 20 percent more of it than of untreated straws. (This is true for all alkali-treated straw.) The pH of the treated straw is 10 or above. The sodium content increases by approximately 0.6 percentage units for every 1 kg NaOH/100 kg added. When treated with 4 kg NaOH/100 kg, titratable alkalinity is equivalent to 0.5 kg NaOH; at 8 kg the amount will be 2.4 kg.

Bulk treatment followed by stacking

When only limited amounts of alkali are used, as in the spray method, one

way to improve the effectiveness of the alkali is to heat the freshly-treated straw to a temperature of 80-90°C. One practical way to do this is as follows: the straw (chopped or shredded) is passed through a specially designed straw treater (Figure 3). In such a treater only small volumes of solution (i.e., 10-20 l/100 kg straw) can be uniformly applied to the straw. The concentration of the solution varies from 25 to 45 percent. The damp, treated straw is then stacked. If the stack is big enough (minimum 3 to 4 tons) the treated straw will heat up to a temperature of 80 to 90°C. The heating is caused by the accumulation of the heat liberated by the chemical reactions between NaOH and the straw. The temperature reaches a peak during the first three days and then declines for another 15 days or so to ambient temperature. As a result of this heating, moisture evaporates; this leaves the straw dry enough to store, provided that the initial moisture content of the straw does not exceed 17 percent before treatment. If the initial moisture content is more than 17 percent, there will be less heating and insufficient drying, leaving a material that will either go mouldy or heat up, owing to bacterial fermentation, to the point of spontaneous combustion. The stack must be made at a well-ventilated site and not put in a silo, where it would not dry out sufficiently to keep. The stack should also not be covered as this would prevent the loss of water vapour. Straw treated in this way is dry, but otherwise resembles daily spray-treated straw. Digestibility is improved by about 15 units.

Bulk treatment followed by ensiling

The results of several experiments have shown that straw spray-treated with 60 to 120 litres of NaOH solution per ton and ensiled can be stored for up to one year. There is no microbial fermentation and the straw remains stable owing to its high pH. It does not heat up significantly, presumably because of its high moisture content. In appearance and feeding value ensiled straw is the same as daily spray-treated straw. The ensiling of treated straw can involve the use of $Ca(OH)_2$. Many experiments have shown that when $Ca(OH)_2$ is sprayed on straw it has little effect on digestibility if the straw is fed to animals the same day or the next day. It can be as effective as NaOH if the sprayed straw is ensiled for about 5 months. Another advantage of the ensiling method is that it offers a way to handle wet straw — straw that is green at harvest or that is rained on after harvest.

Figure 3 *Tractor-powered straw treater. Note caustic soda solution drum at right.* (Credit: Maskinfabriken, Taarup, Denmark.)

Bulk treatment with ammonia in stacks

Ammonia treatment of straw has a strong appeal because of the advantages it has over NaOH treatment (Figure 4). These are: there is no residual alkali produced; and the nitrogen content of the straw is increased. A stack of straw bales 2 m high and 4.5 m square (for example) is made in the open on a groundsheet of 0.2 mm polyethylene 10 × 10 m in size. In building the stack a 2 × 2 cm lath should be placed between the third and fourth layers. The lath will later be pulled out to make a hole into which the ammonia delivery pipe can be inserted. The stack is then covered with a 10 × 10 m top sheet, leaving a free margin of 70 cm all around, which corresponds to the margin of the groundsheet. These margins are then rolled up together and weighted down with sand bags. The delivery pipe from the anhydrous ammonia tanker is then inserted into the stack and NH_3 added at the rate of 3.5 kg/100 kg straw. After withdrawing the delivery pipe, the fourth side is quickly closed. In northern Europe 8 weeks are recommended for treatment during the winter, but in the summer (or throughout the year in warmer climates) the maximum increase in digestibility is achieved in less time — only about 4 weeks. The stack must be aerated for a day or so after opening before the straw is fed to animals. Digestibility increases by about 12 units. The straw is palatable unless it is damp, in which case it will contain some of the (unpalatable) excess unreacted NH_3.

Industrial process

Another practical way to apply heat to freshly treated straw is to put it through a pelleter. The heat created by the pressure produced by the press enhances the effectiveness of the alkali

Figure 4 *A stack of straw bales that has been treated with anhydrous ammonia. Note the careful sealing around the base.* (Credit: F. Sundstøl)

applied. With 4 to 5 kg NaOH/100 kg straw, digestibility increases by about 15 units. The industrial processing of straws has been designed to take advantage of the pelleting process. The increased density of the pelleted straw also makes it easier and cheaper to transport and handle (Figure 5).

The feeding value of alkali-treated straw

Alkali-treated straw can replace hay and silage in the diet if the difference in protein content between the treated straw and the hay or silage is made good with an appropriate protein supplement. In thus using treated straw, however, it must be realized that individual lots will vary widely in digestibility, as do individual lots of hay and silage. The initial digestibility of straw varies between 35 and 55 percent. Treatment increases this by 10 to 20 units depending upon the method used, the extent of increase among straws being more or less independent of initial digestibility. For efficient utilization, farmers will have to be advised as they are for hay and silage; i.e., the digestibilities of individual lots of treated straw will have to be determined by *in vitro* techniques by the advisory service and feeding recommendations made to suit the quality of the straw. Factors that affect initial digestibility are species, variety, year and method of handling.

In southern Asia, where straw is the mainstay of the livestock diet, weight gains in growing cattle and buffaloes can be increased by 0.2 to 0.3 kg/day by treating straw and supplementing it with protein or even urea. In village stock this means at least a doubling of the rate of weight gain and a sizable reduction in age at first calving.

The digestibility of treated straw can be lowered if it is fed in diets with more than about 30 percent concentrates, as is the digestibility of other roughages. In general this depression is greater with highly digestible roughages than with those of lower digestibility. With straws this means that in high concentrate diets the digestibilities of treated and untreated straws often become the same, and so no benefit is derived from treating straw used in such diets. An exception to this appears to be treatment done with 8 kg NaOH/100 kg. The high alkalinity of the straw probably counteracts the tendency with such diets for the pH of the rumen contents to fall and thus ensures the maintenance of conditions favourable to the activity of cellulolytic organisms.

The economic feasibility of feeding animals on alkali-treated straw

Cost analyses have been done on data from many feeding trials conducted in various countries. In Europe the substitution of treated straw for hay and silage in the livestock diet is profitable (at present prices) if the straw has no value, other than the cost of collecting it from the field and treating it on the farm. This substitution will often be profitable even if the straw is purchased from the market and treated on the farm — provided the straw is locally purchased, that is, since transport charges for baled straw are very high. In North America even straw produced on the farm where it is treated and used as feed does not appear to be cheap enough at present to substitute profitably for hay or silage. Treated straw cannot profitably be substituted for barley in intensive barley-based beef-fattening diets in Europe.

A number of straw-processing factories in Europe produce treated straw pellets; these pellets are at present being purchased by feed manufacturers, ground and mixed in commercial

Figure 5 *Aerial view of straw treatment factory. Treated straw pellets are stored in silos at left.* (Credit: Uni-nutrition International Ltd., U.K.)

concentrate mixtures. There is sufficient feeding-trial data at present to evaluate the economics of this practice. Farmers currently buy very little of the treated-straw pellets for use as a replacement for hay or silage, possibly because the price is too high.

In countries where straw is traditionally fed to livestock, alkali treatment is clearly profitable. Feed costs per kg liveweight gain or per kg milk produced are reduced. Earlier maturity of stock is another saving in costs that occurs from the use of treated straw.

Priorities in further research

The highest priority in research needs to be given at present to the utilization of treated straw. A systematic study of the factors affecting the digestibility of straws, treated and untreated, will provide the information needed to ensure that straw is fed to maximum advantage under all circumstances. The need for more information on utilization applies to roughages in general and not only to straw.

Next in importance as a research topic is the further testing and comparing of methods of treatment, and the development of cheap, efficient methods of handling and treating straw on the farm. An attempt should be made to devise systems in which existing farm machinery can be used.

In Europe, the economics of changing farming systems to accommodate straw utilization need to be studied.

Coordinated field testing and demonstration project

High priority must also be given to determining, in physical and economic terms, the benefit of alkali treatment of straw under village conditions in Asia and other areas where straw is the staple feed. This cannot be done realistically on the experiment station. Furthermore, if straw treatment is ever to be used in Asia, its use will have to be demonstrated on farmers' animals in the same way that new crop varieties or agronomic practices are demonstrated in his fields. To meet both needs, the author, when working as consultant for FAO, proposed a field testing and demonstration project. A number of institutions in various countries of Asia, the Near East and Africa were proposed to carry out a common programme in two phases. In the first phase, to last two years, two or three existing methods of alkali treatment, scaled to the appropriate size, will be compared as regards their effectiveness in improving straw quality, measured in terms of a production trial with growing animals at the experiment station. The object of this phase of the project will be to decide upon the treatment method to be used in the next phase in the village. The choice of method will be based upon effectiveness, cost and ease of operation under village conditions. A decision will also have to be made at the time of choosing the method on the scale of treatment; i.e., whether treatment should be organized as an individual farm activity or as a community activity (e.g. the Norwegian cooperative treatment plants).

Once the method is decided, a second phase of four years will start. Individual farmers will be asked to cooperate by making available one or two growing animals. These animals will be randomly allotted, irrespective of owner, to one of three groups. The first group will be fed by the farmer in his usual way, the second will be fed urea and mineral supplements in addition to the usual farm diet of the animals, and the third group will be fed alkali-treated straw with the same mineral and urea supplements as given to the animals in group two. A person will be assigned to each village to: help farmers treat straw and feed animals with these supplements correctly; weigh feeds offered and refused once a month; measure the animals (to estimate weight); and record age at oestrus, first service and first calving or age at market-weight. The economic feasibility of the system will be assessed. With female milking stock, the experiment will continue until the animals have completed their first lactation.

A series of three workshops will be held to plan the work and later to evaluate progress. ■

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Sugar cane as cattle feed

T.R. Preston and R.A. Leng

Part. II: Commercial application and economics

This is the second part of a two-part article. The first part dealt with the nutritional constraints and perspectives of sugar cane as cattle feed. It was published in World Animal Review 27.

The feasibility of using sugar cane in commercial cattle feeding depends on a number of factors. The most important of these are:

- The need for appropriate supplements that ensure an adequate level of animal performance without excessive cost.
- The cost of growing/purchasing and transporting sugar cane.
- The need for a cane-processing system that is appropriate to the scale of operation, i.e. according to whether the sugar cane is being used on a small family farm, a large feedlot or as part of an agro-industrial operation.

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These different aspects are considered in this article.

Supply of supplements

In addition to minerals, the supplements required in sugar cane diets must supply fermentable nitrogen, by-pass protein and by-pass glucose or glucose precursors. All these supplements function as rate-limiting nutrients and each one may be the rate-limiting factor at a given time. The amounts of these to be added to a sugar cane diet will be governed by economic rather than nutritional considerations.

In practice, fermentable nitrogen can always be included in nutritionally optimum amounts as it is cheap and what is not utilized by the animal can be recycled and used as fertilizer.

Sources of by-pass glucose precursors (principally starch) and by-pass protein are almost always expensive when they originate from cereals, oil seeds and animal by-products; hence they generally are used at levels below those required to maximize animal performance.

Supplement formulation

The currently recommended supplement levels for either chopped whole cane or derinded stalk plus tops (70:30 ratio) are:

- 10 g urea/kg fresh cane
- 50 g by-pass protein/100 kg body weight
- 100 g by-pass starch/100 kg body weight
- Minerals and vitamins

Examples of supplements to be given alone or in combination that have yielded good results under commercial conditions are given in the table.

Tropical crops as sources of by-pass nutrients

Considerable success has now been achieved with the use of the legume shrub *Leucaena leucocephala*, either grazed, or cut and carried to the animals. On a fresh weight basis, maximum yields are probably of the order of 50 percent of those of sugar cane. Yields of 75 tons of fresh matter/ha/year (with cutting intervals of 2 months) are presently being obtained in the Seychelles, on relatively poor soils (red earth and coral sands) by intensively recycling cattle slurry (Preston, Davis and Delpeche, 1977). This is equivalent to some 4 tons of protein/ha/year. Good results have also been obtained in Guatemala on alluvial soils, and in Mexico on calcareous

Examples of supplements found to give good results in diets of sugar c[illegible]

Category	Milking cow	Suckling calf [1]	Steer/heifer
Mean liveweight, kg [2]	450	110	300
Rate of supplementation, kg/day			
A. Protein/cereal meal [3]	2.0	0.25	1.2
B. *Leucaena* forage	11.0	1.5	6.0
B. Banana fruit	13.0	2.0	7.0

[1] For early weaned calves, the quantities should be tripled. — [2] Pro rata for different liveweights within each category of stock. — [3] e.g. Rice polishings or whole cotton seed or combinations of 25% fish meal for soybean/rapeseed meal/cotton seed meal) and 75% maize meal.

soils. In Mexico, the system is usually based on restricted grazing about three hours daily (Alvarez and Preston, 1976a).

The cassava crop offers considerable scope as a combined source of protein (from the forage) and of glucose precursors (from the root). The first reports of its use with sugar cane were from the Centro Internacional de Agricultura Tropical, Colombia (Moore, 1976). Its usefulness as a by-pass protein has been less intensively researched than that of *Leucaena*, and there are some suggestions (Meyreles, MacLeod and Preston, 1977) that the protein may be too soluble when cassava is fed to animals fresh. Drying by sun or artificially should help in this respect, and this is being investigated.

Starch-producing plants are the logical sources of glucose precursors. Considerable work has been carried out with cassava root as a source of starch. There were indications of reduced voluntary feed intake when fresh root was given (Alvarez and Preston, 1976b). However, positive responses have been obtained with ground, sun-dried root (Silvestre, McLeod and Preston, 1977), although these have not been as consistent or as large as the increases with rice polishings. It is possible that some of the cassava starch is fermented in the rumen (Ravelo *et al.*, 1978).

Reject bananas gave excellent results as a supplement to molasses/urea in the Philippines (McEvoy and Preston, 1976), and their role with sugar cane is currently being tested in Seychelles. Preliminary results from a 160 day trial indicate that as little as 3 kg fresh fruit (containing approximately 460 g starch) per head daily fed to 200 kg steers increased their growth rate by 20 percent when the

Leucaena leucocephala *growing in Seychelles.*

Leucaena *and cassava forage in Seychelles.*

basal diet was sugar cane/urea and *Leucaena leucocephala*. Growing problems seem few, particularly when linked with a feedlot where unlimited quantities of cattle slurry are available as fertilizer. Estimates of the yield are 60 to 70 tons of fruit/ha/year (about 10 tons of starch/ha) and, with a plantation life of at least ten years, production costs should be low (Delpeche, Davis and Preston, 1978).

Harvesting and processing of sugar cane

Two fairly clearly defined systems of sugar cane feeding seem to be emerging that give consistent economically and technically feasible results — one involving whole sugar cane and the other derinded cane. A third system, based on separation technology, will probably develop where there is production of cane board and synthetic lumber (from cane rind).

Whole sugar cane. The major cost component in using whole sugar cane for feeding cattle is not the growing, but the harvesting, transporting and processing of the cane. Hand harvesting only appears to be economically feasible on small family farms (2-3 ha).

Commercial units that employ paid labour probably have to be fully mechanized; the minimum size of such units is that required to justify investment in a sufficiently robust harvester and a high-powered tractor (at present about US$20 000). A unit of some 1 000 head of cattle (requiring approximately 50 ha of cane) is probably the lower limit, the cane being planted specifically for machine harvesting in the field (i.e. by growing cane varieties that will not lodge and using land free of stones) (Arrivillaga and Preston, 1978).

Derinded cane. The original objective of the inventors of the sugar cane separation technology (E. Tilby and R.B. Miller; see CIDA, 1973) was to produce a raw material (the rind of the cane stalk) that would replace wood in the making of compressed-particle board, with the long-term aim of developing low-cost housing for tropical countries. The sugar-rich pith remaining after the removal of the rind

and the waxy epidermis was intended to enter the traditional sugar-extraction process, or to serve as cattle feed or in the production of alcohol.

These aims are finally at the stage of realization now that it has been demonstrated (Moultner, 1978) that sugar-cane board (made from the rind) is equal or superior to any wood-based particle or laminated board, both in its properties and in its potential uses. A low-cost house constructed entirely from sugar-cane board and sugar-cane lumber now appears to be both technically and economically feasible.

On average, the sugar-rich pith (derinded sugar-cane stalk) is likely to be slightly superior to chopped whole stalk as a feed for cattle (Preston and Leng, 1978). It also has advantages from the point of view of sugar production (Laurie, 1978) since almost all the impurities that cause problems in conventional cane-sugar production are eliminated in the rind.

For cattle feeding it is considerably cheaper to harvest and chop whole sugar cane (in one single operation) than to use the separation technology, which requires the stalk and tops to be delivered to the processing site as discrete components. This economy in harvesting/processing more than compensates for the marginally lower feeding value of whole as compared with derinded cane.

The use of derinded cane for animal feeding will only be appropriate therefore in an integrated scheme where there is associated production and sale of cane board. Such a scheme must be fairly large, since the minimum output for a board factory is likely to be about 20 tons/day of finished product, requiring an input of about 320 tons/day of cane stalk, and producing 250 tons/day of pith for cattle feed (this increases to 350 tons/day when the sugar cane tops are also included). This is sufficient to feed some 16 000 head of cattle daily. The total investment in such an integrated agro-industrial unit is likely to be of the order of US$10-12 million.

Thus, for medium and small scale cattle units, whole-cane technology will certainly continue to be preferred, unless small scale rind-based construction materials, such as cement/rind mixtures for blocks and panels, are developed.

Mechanical harvesting of sugar cane for cattle feeding in Guatemala.

Economics of sugar cane in feeding cattle

It is still too early to generalize about the economics of the use of sugar cane in feeding cattle, as so much depends on local prices for both products and inputs, and on the particular management system that is employed: year-round feeding of sugar cane in confinement; or wet-season grazing, with the sugar cane being fed in simple drylots in the dry season. Moreover, the availability of supplements and their variable composition in different countries requires examination, since only rice polishings, cotton-seed meal, rape-seed meal and whole cotton seed and mixtures of maize and fish meal or soybean meal have supported consistent levels of animal production on sugar cane diets under commercial conditions.

Of the constraints to productivity discussed in Part I of this article, the ones that are not easily overcome, and that are also of major economic importance, are the provision of by-pass protein and by-pass glucose precursors. There are, however, considerable possibilities for the manipulation of rumen function, as discussed earlier, and this promises to give rise to dramatic improvements in productivity on sugar cane diets, particularly at low levels of supplementation with by-pass nutrients. This is the area that requires major emphasis in re-

Creole heifers raised on sugar cane/urea and Leucaena *in Seychelles.*

search, since any reduction in the needs for by-pass nutrients without a concomittant sacrifice in the rate of productivity will lead to considerable benefits in the use of sugar cane for cattle feeding. ■

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Current situation and outlook for animal feeds and animal products*

□ CEREALS

Production. The latest FAO forecast, as of 25 July, foresees a 1978 world harvest of 1.2 million tons of grains, equalling the record production of 1976. Of this harvest, 409 million tons is expected to be wheat, which is used chiefly as food, and 710 million tons coarse grains, used both as food and feed. An estimated 60 percent of the coarse grains will be fed to animals. These forecasts are still subject to later adjustment but they confirm the earlier FAO assessment, published in *World Animal Review* 25, that world grain supplies will be adequate during the current year.

In the USA, the official estimate for the 1978 coarse grains crop is higher than earlier expected owing to the larger area planted. In most of Europe the 1978 cereal harvests were average to good. Total western European wheat and coarse grains production is forecast to be 155 million tons, 2 percent up on a year ago while Eastern Europe is expected to produce some 78 million tons, the same as in 1977. The FAO forecast of total USSR grain production, including rice and pulses, is 215 million tons — about 10 percent above last year's reduced harvest.

In the Far East, plantings of food crops have been favoured by the satisfactory development of the monsoon. In China, an increase of 5 million tons over last year was officially reported for the summer grain harvest. FAO estimates 1978 Chinese wheat production at 43 million tons — nearly 10 percent above the drought-reduced 1977 level. The maize crop in Thailand is estimated at 2.75 million tons (1977: 1.7 million tons).

Near Eastern cereal crops are expected to recover from last year's reduced level.

In Latin America, Argentina's 1978 maize crop, at 9.5 million tons, is 15% higher than in 1977, and the sorghum crop was a record 7.4 million tons. Wheat plantings are expected to total 5.7 million hectares — 24 percent larger than in 1977. Assuming average weather, a 1978 wheat crop of 8 million tons is forecast by FAO for Argentina, compared with only 5.3 million tons in 1977. Because of drought, the Brazilian maize crop just harvested was reduced to about 14 million tons (1977 brought a record 19 million tons). The outlook for the wheat crop for harvest later in the year is not too promising.

In Australia, prospects for the 1978 wheat crop have further improved with the above average rainfall received since June.

The outlook for world rice production in 1978 remains heavily dependent on the further development of this year's monsoon in Asia. Early indications suggest that global output this year could be close to, or somewhat higher than, the long-term trend of production.

Grains as animal feed. The year-to-year world consumption of cereals as animal feed is more volatile than cereal consumption for human food since good harvests for cereals usually coincide with good years for pastures and green fodder, and, conversely poor fodder crop years result in greater need for supplementary feeding. In view of the trend to greater supplementary cereal feeding both in poor pasture years and at times when livestock products enjoy good marketing conditions, larger stocks than used to be carried prior to the 1970s are desirable to assure both food and feed security. The year 1978 is average for forage and also one of relatively slow growth in the output of livestock products. Hence the demand for cereal feedstuffs did not increase rapidly in 1977/78. However, there are signs that grain feeding may increase more quickly in the second half of 1978 as meat prices in the USA and the Near East make the better and quicker finishing of preferred livestock varieties profitable. Currently about one third of all the grains used in the world (including wheat) is used for animal feeding.

Wheat and coarse grain stocks. It is too early for any firm stock forecast for the end of the 1978/79 crop seasons, as production, particularly of coarse grains, can still differ substantially from current expectations. However, based on the increased grain production estimates of the major exporting countries, carryover stocks of wheat and coarse grains at the end of

* As of 18 August 1978. *Source:* FAO Commodities and Trade Division.

their 1978/79 crop seasons may be larger than expected earlier. Stocks for coarse grains, particularly in view of the recent official upward revision of output in the United States, could rise to a new record.

Trade. Global wheat imports in 1978/79 are now forecast to decline by almost 8 percent from the record level last year. This is mainly due to expected better crops in the USSR, China, parts of North Africa and the Near East compared with the 1977/78 season. For coarse grains, 1978/79 world imports are estimated to be over 71 million tons, just 3 percent lower than last year. Projected import requirements have been increased only for Brazil, where the sharp decline in domestic production is estimated to result in even larger imports of maize than expected earlier to meet the rising demand for animal feed.

Mainly because of the larger than expected coarse grain crop in the United States, and the larger export supplies available from the main exporting countries, there has been more than 10 percent reduction in the international price of coarse grains since mid-June but maize and sorghum prices are still over 20 percent up on a year earlier. Wheat prices have held better than those for coarse grains, which fell sharply after the release of the US coarse grains estimate. The price differential between US export prices for wheat and maize has widened to 36 percent against 22 percent in June, and only 15 percent a year ago.

□ CASSAVA

It was mentioned in the last issue that in recent years there was an increase in the EEC in the use of imported non-cereal feeds, including cassava. The EEC use of cassava pellets and cassava chips has risen from little over 2 million tons in 1972 to over 3.6 million tons in 1977 and is expected to be about 4 million tons in 1978. Cassava feedstuffs are also important in Brazil and several other Latin American countries and are becoming increasingly used in Thailand and Malaysia.

□ OILSEEDS, CAKES AND MEALS

International market prices of most oilseeds, cakes and oil meals have declined since mid-year and by early August the US$ values of many of these products were back to the same level as a year ago. These price developments reflect the likelihood of a large output in the coming season. Nevertheless, at this early stage, production prospects for the 1978/79 season are clearly subject to a wide margin of error and may change significantly as the season progresses. Weather conditions will continue to have a major influence on the outcome of northern hemisphere annual crops until harvests are actually completed later in the year while southern hemisphere annual crops have still to be sown; the effect of weather on the output of tree crops may also prove considerable.

With these uncertainties in mind, a first tentative forecast on the basis of information available as of mid-August, and assuming normal weather conditions, indicates increases in the production of most major oilseed crops in the 1978/79 season compared with the preceding one.

By far the largest expansion is anticipated in world soybean production. In its latest report (based on conditions on 1 August) the United States Department of Agriculture (USDA) forecasts a new record US crop of 48.0 million tons (3 percent more than the preceding year), reflecting record plantings, which more than offset the likelihood of somewhat below-trend yields. With beginning stocks also larger — though by much less than anticipated earlier in the season — total US supplies are estimated at a new record of 51.4 million tons. Total disappearance is however also expected by the USDA to increase slightly so that end of season stocks of US beans are forecast to be only marginally larger than 12 months earlier; at 3.5 million tons, they would represent 4-5 weeks of US soybean average annual disappearance in the last three seasons. A sharp recovery to a new record level is generally forecast for the soybean crop in Brazil to be harvested in early 1979, following the low yields this year owing to drought; though largely speculative at present, forecasts published so far range from between 13.0 and 14.5 million tons. Much of the expected increase is likely to be available for export, but not necessarily in the form of larger shipments of soybeans as such, as crushing capacity has been expanding rapidly. Some further increase in the 1979 soybean crops in Argentina and Paraguay appears also probable.

World groundnut output is expected to show some increase, mainly as a result of better crops currently forecast in India and West Africa. The level of world production of sunflower seed will be largely determined by the USSR crop, the outcome of which is still very uncertain, though some gain over last season is generally expected. Another expansion, though less marked than in the preceding season, is forecast for the sunflower seed crop in the United States, a country which, in recent years, has become a major exporter. World rapeseed production will be boosted by an expected record crop in Canada, where plantings, in response to favourable world market prices compared with alternative crops, have increased over 75 percent above last year. In contrast, some decline is expected in world cotton seed output, particularly due to lower production in the United States.

The world production of oilcakes and meals in 1979 is expected to grow somewhat more (both in relative and volume terms) than that of edible/soap fats and oils, owing to the predominant share of soybeans (with a high protein meal content compared with other oilseeds) in the overall expansion in oilseed crops expected next season. Production is tentatively forecast at a record 37.9 million tons (protein equivalent), 2.2 million tons more than last year, and 2.0 million tons above the long-term trend. If this level of output was achieved, supplies of oilmeals should be sufficient although, as in the case of fats and oils, unforeseen crop shortfalls, particularly of soybeans, would considerably alter this outlook.

Selected index numbers with comparisons

	July 1977	*July 1978*	*Change from year ago*
US feedstuffs price index	184	200	+16
US feedgrain index	142	169	+27
FAO oilcake and meal index	209	208	— 1.0
US pig/maize ratio	23.8	22.3	— 1.5
US cattle/maize ratio	22.6	25.9	+ 3.3

Feedstuff market summary. Overall demand for marketed feedstuff concentrates in the first seven months of 1978 did not rise greatly in the largest markets, i.e., North America and Western Europe. The best buying interest came from dairy, pig and poultry farmers. Fish meal prices moved up sharply and cotton seed meal was also stronger in July than during the first half of 1978.

□ MEAT

Strong demand for beef and sheep meat has led to increases in international prices of these products in 1978. The improvement in sheep meat price was a continuation of the recovery which began in 1976 but the increase in beef prices is a recent phenomenon. Since the beginning of the year the London market quotation for frozen New Zealand lamb has increased by 16 percent. This continued rise in prices reflects strong import demand particularly from the Near East at a time when export supplies from Oceania are showing a cyclical decline.

In the first half of 1978 international beef prices had shown divergent tendencies in different markets until the announcement in June of an increase in US imports under voluntary restraint agreements. This increase of 90 000 tons in addition to 590 000 tons agreed earlier, led to sharply increased beef prices. While the demand for beef is also strong in the petroleum exporting developing countries, reduced purchases have been made by centrally planned countries where local production continues to increase.

In the United States rising disposable incomes have meant strong demand for beef. Pig production, which had been expected to increase in view of lower grain prices and rising beef prices, has shown little change from year earlier levels but poultry production has increased by approximately 8 percent. Helped by the weaker dollar the United States has also increased poultry exports, particularly to the Near East. There is strong competition in these export markets from Latin America and the EEC. Poultry prices in international trade remain substantially below the domestic prices in Western Europe and in mid-May the EEC increased its export refunds.

World output of sheep and goat meat is unlikely to grow in 1978/79. Although production is rising in Europe and a cyclical upswing in output is expected in New Zealand, production is expected to fall further in Australia where sheep numbers in early 1978 were the lowest since 1954. The cyclical rebuilding of the Australian flock may start in 1978/79.

Demand for beef is also expected to continue to be relatively strong but world output could fall. North American beef output will continue to fall in 1978/79 since cattle numbers have contracted sharply in the past few years. In the first half of this year, with strong demand for stock for fattening, breeding stock were reduced. Cattle numbers have also been reduced sharply in Australia – but with improved prices and satisfactory weather some cyclical rebuilding of herds may have now commenced, leading to lower beef production in 1978/79. In New Zealand it appears that while there was only a slight drop in cattle numbers last year, slaughterings — particularly of cows — in the period October 1977 to March 1978 were far higher than the corresponding period of 1976/77. In the other major southern hemisphere exporter, Argentina, an increase in production is expected this year due to continued high rates of slaughter. Increased production is also forecast in the USSR and Eastern Europe, where cattle numbers now stand at record levels. Little increase is expected in Western Europe. The output trend in the EEC is uncertain. Higher beef production there would reflect the effects of measures to encourage dairy farmers to give up milk production. The response to these measures was poor in 1977/78.

It appears that world beef output will be reduced for the next few years with a consequent improvement in prices. However, unless there is a deterioration in the feed supply situation, there is unlikely to be a dramatic increase in prices as there was in the early 1970s.

Assuming adequate feed supplies, production of poultry and pig meat should continue to grow relatively rapidly in the developing regions, Japan, Eastern Europe and the USSR. With favourable livestock/feed prices, and higher beef prices, North American production of poultry and pigs should also increase. The expansion of pig meat and poultry meat production could also accelerate in Western Europe.

□ MILK AND MILK PRODUCTS

The expansion of world milk production virtually came to a halt in the first half of this year. Although milk output still grew by over 3 percent in the EEC, it stagnated elsewhere in Western Europe. In the Soviet Union, milk collection fell slightly and in Eastern Europe it virtually levelled off. Milk output in the United States has been lower than last year and production has been down substantially in Oceania owing to severe drought. A rapid increase in Japan and rises in the developing regions were not enough to compensate for the decreases listed above.

The short-term outlook is for a levelling off of output in the United States and a further slowdown in the growth of EEC production, while there could be some recovery in the USSR, Eastern Europe and Oceania. In Eastern Europe and the USSR, dairy cow numbers are on the increase and with a better feed supply situation than in 1977/78, milk production could

Dairy cow numbers in selected countries

(Thousand head)

Producer	1975/76	1976/77	1977/78
Asia and Oceania			
Australia	2.47	2.28	2.19
New Zealand	2.09	2.07	2.07
Japan	0.94	0.97	1.01
Eastern Europe			
USSR	41.92	41.99	42.60
Poland	5.89	5.65	5.67
EEC	24.81	25.01	25.09
North America			
United States	11.09	11.03	10.93
Canada	2.13	1.96	1.94

Source: FAO.

show a rise in 1978/79. Yet consumption of milk and milk products is also rising, benefiting not only by population and income growth, but also by large scale subsidization. Thence, export supplies of Eastern Europe might not continue their recent expansion, and, if feed and fodder crops fall short of current expectations, the USSR might actually purchase milk products again on the international market.

The levelling-off of milk production in the United States, after two years of expansion and in spite of a still favourable milk/feed price ratio, is mainly due to an accelerated reduction of dairy cow numbers in the context of this year's sharp increase in slaughter cattle prices. However, unlike most other developed market economies, US demand for milk and milk products has been on the increase this year. Although stocks of butter and skim-milk powder are still large, support purchases will probably be considerably lower than in 1977, and some rise in milk product prices above support price levels is expected on the US market. But, unlike in the beef sector, no relaxation of US dairy import restrictions appears probable at this stage, though there may be a rise in imports of those dairy products not subject to quotas.

In Japan, rapidly growing production has been outstripping demand, causing a build-up of stocks and a reduction of imports, especially butter and skim-milk powder.

In Canada and in Western Europe outside EEC, policy action to adjust milk output to commercial outlets has been relatively successful in 1977 and 1978. In the EEC, intensified measures to encourage farmers to give up dairying should bring about some further reduction in milk production growth rates in the second half of this year. However, demand continues to be slack.

With export supplies increasingly concentrated in the EEC and import demand of the developing countries, especially those of OPEC, still growing, prices in the international dairy trade could strengthen. Current prices, at around US$425-500 and US$800-825 per ton f.o.b. for skim and whole milk powder respectively, and US$ 1 300 and US$1 000-1 100 per ton f.o.b. for butter oil and butter respectively, are already higher than a year ago, though most of this increase simply reflects the depreciation of the US currency. ■

Post-graduate programmes in animal health and production offered by the J. Cook University, Queensland, Australia

The following programmes are offered:

1. M.Sc. Course in Tropical Veterinary Science: 12 months' duration. Major components: applied pathology, microbiology, parasitology, epidemiology and animal production with emphasis on tropical agronomy, ruminant nutrition, reproductive physiology and animal breeding. A biometrics component is included. Applications are now being considered for the Course commencing in February 1980.

2. M.Sc. and Ph.D. Research Programmes: Research work in the general fields stated. Major projects in progress include aspects of the pathology of livestock, virology, immunology, helminthology, ruminant nutrition, reproductive physiology and animal breeding. Applicants, who must be graduates in veterinary science or related disciplines, can be considered for acceptance at any time.

Applicants should apply to the Registrar, James Cook University of North Queensland, Townsville, Queensland 4811, Australia.

✠ Mr. H.S. Caldwell, F.R.C.V.S., D.V.S.M.

The death has been announced of Mr. H.S. Caldwell, F.R.C.V.S., D.V.S.M., a veterinarian of very wide experience and with an international reputation, who had worked for FAO in a number of countries of Latin America and Africa.

In recent years he was closely associated with the preparation of "The Husbandry and Health of the Domestic Buffalo" in Rome, assisting both in the task of editorship and in the compilation of the extensive bibliography. His meticulous attention to detail, combined with considerable literary ability, was demonstrated when he undertook to condense, abridge and update the recent FAO publication "The Water Buffalo."

FAO/SIDA courses in veterinary pathology

Since 1962 a nine-month international post-graduate course in veterinary pathology has been given every two years under the sponsorship of the FAO/SIDA (Swedish International Development Authority) Government Cooperative Programme. The number of participants per course is normally fifteen, and many countries in Asia, Africa and Latin America have sent participants to this course.

The courses start with about six weeks of general pathology and histopathology. Five months are spent on training in post-mortem work combined with conferences and including histopathology and microbiology for establishing the final diagnosis of each case. At the end of this period, each participant will have performed more than one hundred post-mortem examinations. There is also a five-week course in microbiology and a two-week course in clinical pathology led by professors of these disciplines. In addition, some 40 specialists give lectures in their special fields.

Each participant is required to present four seminars: one on the animal disease problems in his or her home country; one on a given topic in general pathology; one in microbiology; and one in special pathology. All participants also undertake a minor research project, the results of which are presented at the end of the course.

During the course the participants are taken on trips to scientific institutes of veterinary medical interest in various parts of Sweden as well as in the neighbouring Nordic countries.

Social activities are also arranged by the course directors and the student union of the Swedish University of Agricultural Sciences to acquaint participants with Swedish customs and ways of life.

The intervening year between courses is devoted to follow-up activities by the course directors. These include visits to previous participants as well as the conduct of a regional seminar for the benefit of former participants in one or another region. The course directors also act as consultants and are frequently able to give advice and help in acquiring material necessary for progress in the work of previous participants.

Participants in the courses are selected from among candidates nominated by governments at the invitation of FAO. Admission requirements include a veterinary degree with post-graduate training and at least five years' experience in veterinary pathology. The courses are conducted in English.

Further information may be obtained from the Course Director at the following address: FAO/SIDA Veterinary Pathology Course, c/o SIDA, Fack, S-105 25 Stockholm, Sweden.

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